Average Traffic Speed:

Make this adjustment if the average speed differs from 55 mph. If the average truck speed differs with direction, treat the uphill and downhill traffic separately. Select the appropriate adjustment factors from Table 7 below, entering them in column 18 of Worksheet C.

Table 7

Average Traffic Speed MPH	Heavy Truck Speed Adjustment Factor
50 or less	0.81
55	1.00
60	1.17
65	1.38

Once you have found the speed adjustment factor, you can combine the uphill and downhill traffic. For uphill traffic, multiply the gradient factor times the speed adjustment factor times uphill traffic volume (truck ADT column 19) (assuming one half the total 24-hour average number of trucks unless specific information to the contrary exists), entering the product in column 20. Multiply the speed adjustment factor for downhill traffic times the downhill traffic volume (truck ADT/2 column 19). Add the values for uphill and downhill traffic, entering this sum in column 21. You may now complete the assessment of heavy truck noise without regard to uphill and downhill traffic separation.

Stop-and-Go Traffic:

If there is a stop sign (remember, not a traffic signal) within 600 feet of an NAL for the site on the road being assessed, find the adjustment factor determined according to Table 8. Enter it in Column 22 of Worksheet C.

Table 8

Heavy Truck Traffic Volume per Day	Heavy Truck Stop-and-Go Adjustment Factor
Less than 1200	1.8
1201 to 2400	2.0
2401 to 4800	2.3
4801 to 9600	2.8
9601 to 19,200	3.8
More than 19,200	4.5

Nighttime Adjustment

After all the above adjustments are made, do not forget to adjust for nighttime operations if they are not 15 percent of the total ADT, using the factors obtained from Table 5 just as for automobiles. Enter this value in column 23 of Worksheet C.

At this point, multiply the adjustment factors for nighttime and stop-and-go traffic times the heavy truck traffic volume in column 21 to find the adjusted heavy truck ADT, entering the product in column 24. Use this value and the effective distance from the NAL to the road to find the truck DNL from Workchart 2, entering your answer in column 25 of Worksheet C. If no shielding barriers are to be considered, combine the DNL from heavy trucks with the DNL from automobiles (column 14). The result is the DNL from the road being assessed and should be entered on Worksheet C.

But:

If a shielding barrier is to be considered for the site, make the analysis described below separately for automobiles and then for heavy trucks *before* combining the DNL values. This step is necessary since barriers are far more effective for automobiles than for heavy trucks. Once you have found the amount of attenuation provided by the barrier for automobiles, enter it in column 15. Find the value of barrier attenuation for heavy trucks and enter it in column 25. Subtract these attenuation values from the DNL values obtained previously (columns 14 and 24), entering the reduced DNL values in columns 16 and 27. Combine the automobile and heavy truck DNL values, reduced by the attenuation provided by the barrier, to find the final DNL produced by the roadway at the site.

Remember to combine the contributions to DNL of *all* roads that affect the noise environment at each NAL for the site to obtain the total DNL from all roadways. Enter this DNL on both Worksheet C and the summary Worksheet A.

Attenuation of Noise by Barriers

Noise barriers are useful for shielding sensitive locations from ground level noise sources. For example, a barrier may be the best way to deal with housing sites at which the noise exposure is not acceptable because of nearby roadway traffic.

A barrier may be formed by the road profile, by a solid wall or embankment, by a continuous row of noise-compatible buildings, or by the terrain itself. To be an *effective* shield, however, the barrier must block all residential levels from line of sight to the road; it must not have any gaps that would allow noise to leak through.

Some Preliminary Matters:

In evaluating noise barrier performance, you will be working with different kinds of "distances" between the sound source, the observer, and the barrier.

Actual Distance – the existing distance that would be measured using a tape measure with no corrections or adjustments. This may mean one of two things, *depending on the application;* either the:

- *slant distance* – the actual distance,

Example 11: Road No. 2 has a stop sign at 390 feet from NAL No. 2. There is also a road gradient of 4 percent. No heavy trucks are allowed on this road, but a schedule shows an average of 12 large buses pass along the road per hour between 7 a.m. and 10 p.m., although no buses are scheduled during the remaining nighttime period. The buses are equally divided in each direction along the road. (Remember large buses, those that carry over 15 seated passengers, count as heavy trucks.)

We find the ADT for the "heavy trucks" (the buses in this case) by multiplying the average number of vehicles per hour by the number of hours between 7 a.m. and 10 p.m. That is, 12 x 15 = 180, or 90 vehicles in each direction. We find from Table 6 that the gradient adjustment factor for uphill traffic is 2.0. We find the truck volume adjusted for gradient is

uphill:	*90 x 2.0 = 180*
downhill:	*= 90*
total (column 21)	*= 270 vehicles*

From Table 8, we find the adjustment factor for stop-and-go traffic to be 1.8.

We also remember that we have no buses in the nighttime period and find the factor in Table 5 on page 8 for zero nighttime operations to be 0.43.

Our final adjusted ADT is (column 24)

1.8 x 0.43 x 270 = 209 Vehicles

From Workchart 2, with an effective distance of 174 feet, we find a DNL of 59 dB.

Example 12a: Road No. 3 is a depressed highway and the profile shields all residential levels of the housing from line of sight to the traffic. The average truck speed is 50 mph. The ADT for heavy trucks is 4400 vehicles. We adjust for average speed (from Table 7)

4400 x 0.81 = 3564

and find from Workchart 2 that, with an effective distance of 270 feet, the DNL from truck noise would be 69 dB if no barrier existed. We proceed to analyze the barrier attenuation.

measured along the line of sight between two points; or the

- *map distance* – the actual distance, measured on a horizontal plane, between the two points, as on a map or on the project plan.

For an observer high in an apartment tower, the slant distance to the road may be much longer than the map distance.

Barrier effectiveness is expressed in terms of noise attenuation in decibels (dB), determined with the aid of Workchart 6. This numerical value is subtracted from the previously calculated DNL in order to find the resultant DNL at the Noise Assessment Location.

Note: A noise barrier can be considered as a means of protecting a site from noise even if it cannot wrap around the site to shield from view practically all of the source of noise at every sensitive location on the site. It must be recognized, however, that such a barrier is much less effective than an ideal barrier. (See Workchart 7 and Step 6 below.)

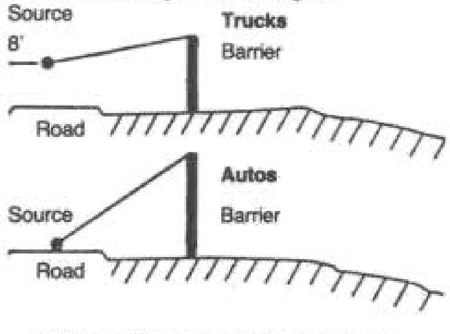
Barriers of reasonable height cannot be expected to protect housing more than a few stories above ground level. Barriers will generally protect the ground and the first two or three floors, but not the higher floors. If there are to be frequently occupied balconies on the upper levels, one solution is to move the building farther from the noise source and face the sensitive areas away from the noise.

Steps to Evaluate a Barrier

1. For the observer's position, use the mid-height of the highest residential level. For the source position, use the following heights (see Figure 7):

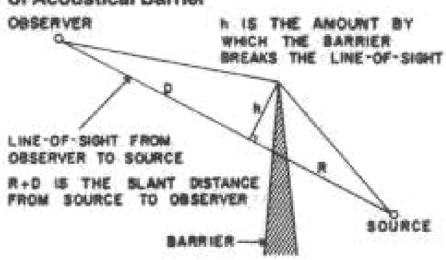
- autos, medium trucks, railway cars – the road or railway surface height
- heavy trucks – 8 feet above the road surface
- diesel locomotives or trains using horns or whistles at grade crossings – 15 feet above the rails.

Figure 7.
Source Heights to Be Used in Roadway Barrier Designs



Get accurate values for the following quantities: h, the shortest distance from the barrier top to the line of sight from source to observer; R and D, the slant distances along the line of sight from the barrier to the source and observer, respectively (see Figure 8).

Figure 8.
Generalized Geometry of Acoustical Barrier



Specifically, R and D are the two segments into which h breaks the line of sight. Note that h is *not* the height of the barrier above the ground but the distance from the barrier top to the line of sight.

2. Enter at the top of Workchart 6 with the value of h on the left-hand scale; move right to intersect the curve corresponding to R (or D, whichever is *smaller*).

3. Move down to intersect the curve corresponding to the value of D/R (or R/D, whichever is *smaller*).

4. Move right to intersect the vertical scale in order to find the barrier shielding value A in decibels.

5. Interruption of the line of sight with a barrier between the noise source and an observer reduces the amount of sound attenuation provided by the ground. Find the amount of this loss B from the table on Workchart 6 by entering the table with the value of D/R. Find the barrier attenuation value S corresponding to an ideal barrier that completely hides the noise source from view by subtracting B from the value of A obtained in Step 4.

6. If the barrier exists along only a part of the road so that unshielded sections of the road would be visible from the site, the barrier is less effective than an ideal barrier. On a plan view of the site, locate the two ends of the barrier and draw lines from these points to the Noise Assessment Location. Use a protractor to measure the angle formed at the NAL by the two lines. Enter the horizontal scale of Workchart 7 with the values of this angle; read up to the curve having the value of S determined from Step 5 (interpolating if necessary); read left across to the vertical scale labeled "actual barrier performance" to find the value of FS to use for the actual barrier in question.

7. Subtract the barrier attenuation value S (or FS if adjusted for finite barrier length according to Workchart 7) from the value of DNL previously determined to reevaluate the site with the noise barrier in place.

Example 12b: (Refer to Figure 9.) Six stories are planned for the housing where the site has an elevation of 130 feet. The effective elevation for the highest story is found by multiplying the number of stories by 10 feet, adding the site elevation, and subtracting 5 feet.

(6 × 10) + 130 - 5 = 185 feet

The barrier, which in this case is formed by the road profile, has no "height" other than the elevation of the natural terrain above the noise sources traveling on the roadway. The important dimensions are indicated in Figure 9.

Some people with a technical background will be able to fit the geometric diagram to the site situation readily, working from the project drawings and a scratch sheet.

But if you are *not* confident of your geometry, Workchart 5 gets you the values of R, D, and h from the map distances and elevations of the site. We illustrate that procedure in this example.

First, enter the elevations of the source (S), the observer (O), and the top of the barrier (H), as well as the map distances from the barrier to the source (R') and observer (D'), at the top right of Workchart 5. Then, follow the steps on that Workchart to derive the values of h, R, and D that are needed in using Workchart 6.

Entering Workchart 6 at the upper left with the value of h (5.5 feet), we move horizontally

Figure 9.
Detail of Site Showing Measurements Necessary for a Barrier Adjustment

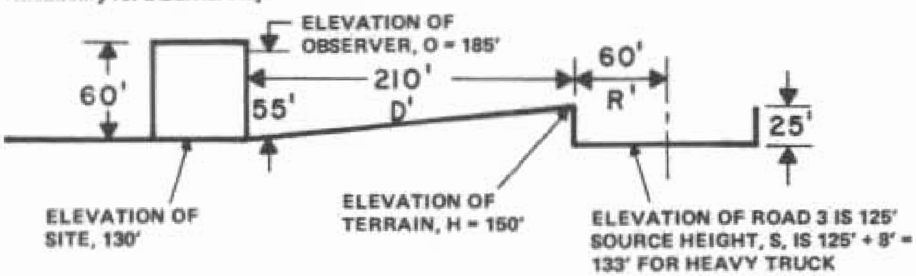
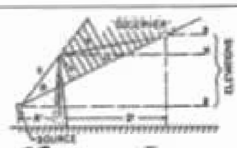


Figure 10.
Use of Workchart 5 to Determine Barrier Dimensions in Example 12b

Workchart 5
Noise Barrier
To find R, D and h from Site Elevations and Distances

Enter the values for:
H= 150 R'= 60
S= 133 D'= 210
O= 185

Fill out the following worksheet (all quantities are in feet)

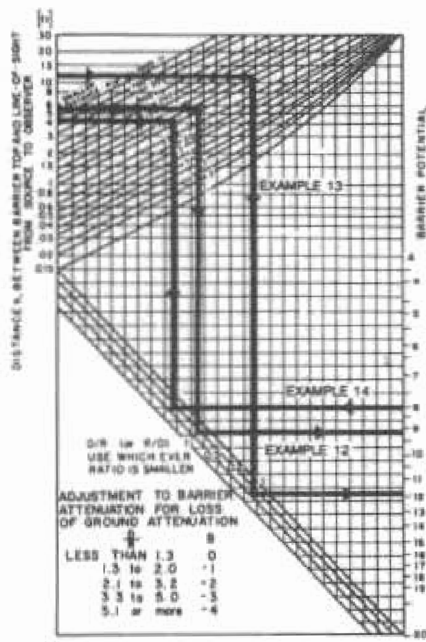


1. Elevation of barrier top minus elevation of source	[H 150]	−	[S 133]	=	[1 17]	
2. Elevation of observer minus elevation of source	[O 185]	−	[S 133]	=	[2 52]	
3. Map distance between source and observer (R' + D')					[3 270]	
4. Map distance between barrier and source (R')					[4 60]	
5. Line 2 divided by line 3	[2 52]	÷	[3 270]	=	[5 0.19]	
6. Square the quantity on line 5 (i.e., multiply it by itself); always positive	[5 0.19]	×	[5 0.19]	=	[6 0.04]	
7. 40% of line 6	[0.4]	×	[6 0.04]	=	[7 0.016]	
8. One minus line 7	[1.0]	−	[7 0.016]	=	[8 0.984]	
9. Line 5 times line 4 (will be negative if line 2 is negative)	[5 0.19]	×	[4 60]	=	[9 11.4]	
10. Line 1 minus line 9	[1 17]	−	[9 11.4]	=	[10 5.6]	
11. Line 10 times line 8	[10 5.6]	×	[8 0.984]	=	[11 5.5]	= h
12. Line 5 times line 10	[5 0.19]	×	[10 5.6]	=	[12 1.06]	
13. Line 4 divided by line 8	[4 60]	÷	[8 0.984]	=	[13 61]	
14. Line 13 plus line 12	[13 61]	+	[12 1.06]	=	[14 62]	= R
15. Line 3 minus line 4	[3 270]	−	[4 60]	=	[15 210]	
16. Line 15 divided by line 8	[15 210]	÷	[8 0.984]	=	[16 213]	
17. Line 16 minus line 12	[16 213]	−	[12 1.06]	=	[17 212]	= D

(Note: the value on line 2 may be negative, in which case so will the values on lines 5, 9, and 12; line 1 may also be negative. Remember, then, in lines 12, 14, and 17, that adding a negative number is the same as subtracting: x + (−y) = x − y. And subtracting a negative number is like adding: X − (−y) = x + y.) Round off R and D to nearest integer; h to one decimal place.

Figure 11.
Use of Workchart 6 to Evaluate Barrier in Examples 12b, 13 and 14

Noise Barrier Workchart 6



to the right until we meet the value of R or D, whichever is smaller: in this example, R = 62 feet. From that point we drop vertically downward until we meet the value of R/D or D/R, whichever is smaller: in this case, R/D = 0.29. From that point, move horizontally to the right to find the value for A = 9 dB. Entering the table for determining loss of ground attenuation effect due to the barrier with a value for D/R of 3.5, the reduction in attenuation (B) is found to be 3 dB. Substracting 3 dB from 9 dB provides a net attenuation of 6 dB. With 6 dB of attenuation, the original DNL of 69 dB (Example 12a) is reduced to 63 dB.

Example 13: An alternative approach, which is somewhat more direct, is illustrated here for the noise of automobiles on Road No. 3.

A preliminary step is to make an accurately scaled sketch of the general geometry introduced on page 8. It must include the positions of the source (this time at the road surface), the observer, and the top of the barrier; and will show the distances h, R, and D. Such a sketch is shown superimposed on the profile of the road and its neighborhood in Figure 12.

If we carefully scale the dimensions directly from this sketch, we find the following values for h, R, and D:

R=63 feet

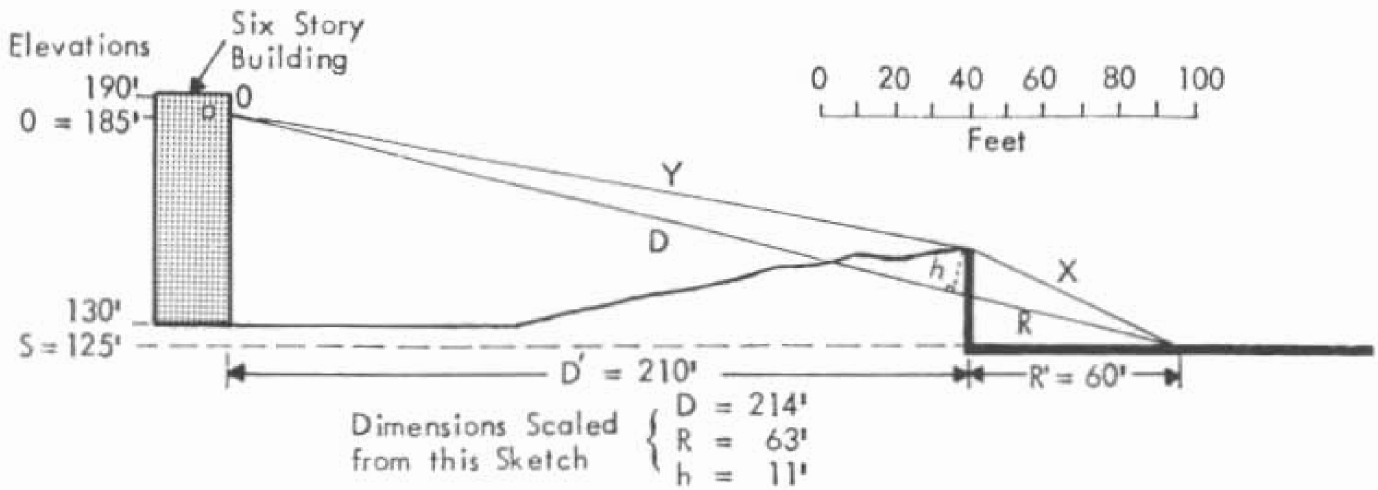
R/D=0.3

D=214 feet

h=11 feet

The barrier attenuation is found, by entering Workchart 6 with these values, to be A=12 dB. It is larger than that found for trucks because the noise source is lower and is, therefore, better shielded by the barrier. The loss from ground attenuation is again B=3 dB for a net attenuation of 12 - 3 = 9 dB. In Example 9b, we found that the DNL

Figure 12.
Sketch Showing Dimensions for Example 13



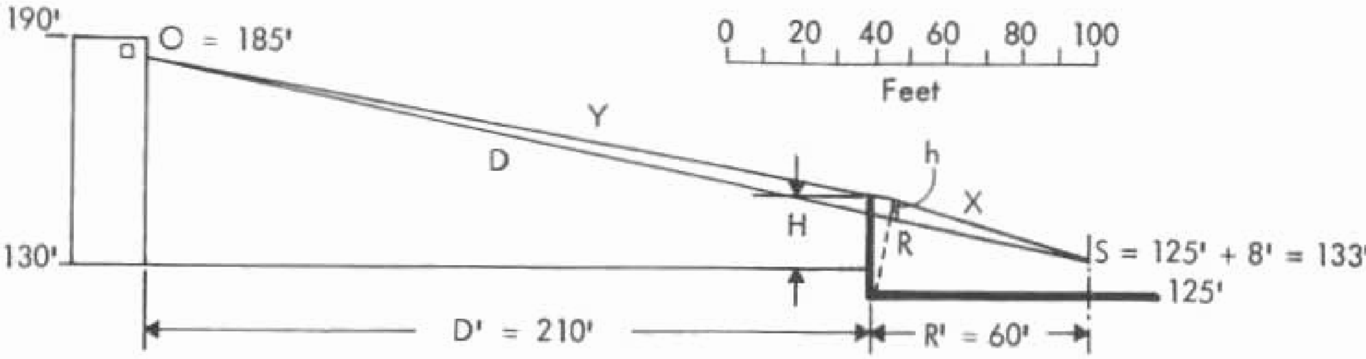
for the projected traffic volume of 100,000 vehicles per day was 69 dB if no consideration was given the shielding provided by the terrain. Subtracting the 9 dB attenuation from 69, we find the partial DNL for automobiles is 60 dB.

In order to find the combined truck and automobile noise for Road No. 3, we combine the 63 dB of truck noise with the 60 dB of automobile noise using Table 1. We find that 1.8 should be added to 63 dB, for a combined DNL of 64.8 dB, or 65 dB when rounded to the nearest whole number.

Example 14: Where no natural barrier exists, Workchart 6 can be used in reverse to estimate the height of a barrier needed to obtain a required attenuation. In example 9b we found that, without any attenuation from terrain or a barrier, the automobile traffic produced a DNL of 69 dB, and in Example 12a the heavy truck traffic produced a DNL of 69 dB. When combined, the total DNL is 72 dB. Suppose the terrain were not rising between NAL and Road No. 3, as shown in Figure 12, but instead was level between the NAL and the edge of the road, as shown in Figure 13. We want to find out how high a wall, infinite in length, would be required at the edge of the road to reduce the combined truck and automobile noise to less than 65 dB. We have found in the previous examples that a barrier of a given height will provide more attenuation for automobiles than it will for trucks. As a first step in our analysis, we will find the height of a wall that will reduce the truck noise to just below 65 dB, say 64 dB, and then find out whether the additional attenuation it provides for automobile noise will be sufficient to reduce the combined truck and automobile noise to less than 65 dB. We begin by finding the height of wall that will provide 5 dB attenuation for truck noise.

We estimate that the ratio of R/D is about the same as R'/D', the ratio of horizontal distance in Figure 13, which is equal to 0.29. Before entering Workchart 6, we find from the loss of ground attenuation table that for D/R = 3.4 we will lose 3 dB attenuation from an ideal barrier. In order to have a net attenua-

Figure 13.
Sketch Showing Dimensions for Example 14



tion of 5 dB, we must have an ideal barrier that provides 5 + 3 = 8 dB attenuation.

Entering Workchart 6 on the right side scale A at 8 decibels, we move across to the diagonal lines, finding 0.29 by interpolating between the lines marked at 0.2 and 0.5. Moving directly up to a point midway between the R lines of 50 and 70, we find our estimated R of approximately 60. Moving across to the left we find that the line of sight between the observer and the truck source height must be broken by a value of h equal to 4.5 feet.

We can determine the height of the wall H in several ways. By drawing h = 4.5 feet to scale on Figure 13, we can scale the total wall height H to be approximately 20 feet. Those who feel comfortable with geometry can calculate H by using the similar triangle relationships in Figure 13 to determine that H is 19.1 feet.

Now we must find how much a wall 19 feet high will attenuate automobile noise, remembering that the source height for automobiles is at the road surface elevation of 125 feet. By scaling the drawing, or by geometry, we determine that the line of sight between the observer position and the automobile source is broken by a value of h that is approximately 13 feet. Entering Workchart 6 at 13 feet we find, for R=60 feet and R/D=0.29, that the potential barrier attenuation is 12dB. We must reduce this by 3 dB for loss of ground attenuation to find the actual shielding of automobile noise to be 9 dB. The original 69 dB of automobile noise is reduced to 69 - 9 = 60 dB.

Finally, we combine the heavy truck noise, attenuated by the wall to 69 - 5 = 64 dB, with the automobile noise reduced to 60 dB, to find a combined DNL of 65.5 dB, or 66 dB when rounded upward. Remember, however, that this is for an infinite wall. Further adjustments would have to be made once the actual length was known.

Railways

Necessary Information

To evaluate a site's exposure to railway noise, you will need to consider all rapid transit lines and railroads within 3000 feet of the site (except totally covered subways). The information required for this evaluation is listed below under headings that indicate the most likely source.

Before beginning the evaluation, you should record the following information on Worksheet D:

From the area map and/or the (County) Engineer:

- The distance from the appropriate NAL on the site to the center of the railway track carrying most of the traffic.

From the Supervisor of Customer Relations for the railway:

- The number of diesel trains and the number of electrified trains in both directions during an average 24-hour day.
- The fraction of trains that operate during nighttime (10 p.m. - 7 a.m.) If this is unknown, assume 0.15.
- The average number of diesel locomotives per train. If this is unknown, assume 2.
- The average number of railway cars per diesel train and per electrified train. If this is unknown, assume 50 for diesel trains and 8 for electrified trains.
- The average train speed. If this is unknown, assume 30 mph.
- Is the track made from welded or bolted rails?

From the Engineering Department of the railway:

- Is the site near a grade crossing that requires prolonged use of the train's horn or whistle? If so, where are the whistle posts located? (Whistle posts are signposts which tell the engineer to start blowing the horn or whistle. Every grade crossing has whistle posts and they are listed on the railroad's "track charts." If traffic on the track is one-way, there will be only one whistle post. The grade crossing itself is the other "whistle post."

Electrified rapid transit and commuter trains that do not use diesel engines should be treated the same as railway cars.

Note: Buildings closer than 100 feet to a railroad track are often subject to excessive vibration transmitted through the ground. Construction at such sites is discouraged.

Evaluation of Site Exposure to Railway Noise

Railway noise is produced by the combination of diesel engine noise and railway car noise. These Guidelines provide for the separate evaluation of diesel locomotives and railroad cars, and then the combination of the two, in order to obtain the DNL from trains. When rapid transit or electrified trains that do *not* use diesel engines are the only trains passing near a site go directly to the second part of the evaluation since these trains are treated in the same manner as railway cars.

Diesel Locomotives

Workchart 3 was derived with the following assumptions:

- A clear line of sight exists between the railway track and the Noise Assessment Location.
- There are two diesel locomotives per train.
- The average train speed is 30 mph.
- Nighttime operations are 0.15 of the 24-hour total.
- The site is not near a grade crossing requiring prolonged use of the train's horn or whistle.

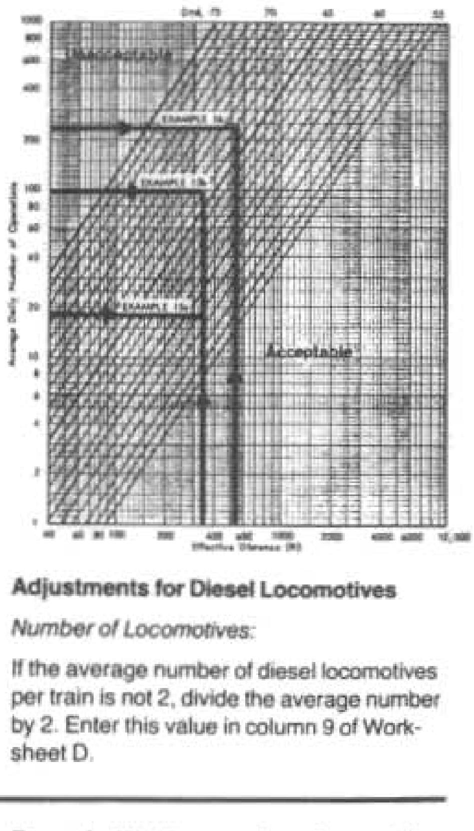
If the situation meets these conditions, proceed to Workchart 3 for an immediate evaluation of diesel locomotive noise.

But:

If any of the conditions is different, make the necessary adjustments listed below and *then* use Workchart 3 for the evaluation.

Figure 14.
Use of Workchart 3 to Evaluate Diesel Locomotive Noise

Railroads – Diesel Locomotives



Adjustments for Diesel Locomotives

Number of Locomotives:

If the average number of diesel locomotives per train is not 2, divide the average number by 2. Enter this value in column 9 of Worksheet D.

Example 15a: The distance from NAL number 1 to Railway Number 1 is 339 feet. Two percent of the 35 daily operations occur at night; there is clear line of sight between the tracks and the NAL, and no horns or whistles are used. No information is available on train size or speed, therefore we will assume 2 engines per train and a speed of 30 mph.

Since the percentage of nighttime operations is different from 15 percent, we must adjust the actual number of daily operations, multiplying by 0.50 according to Table 5.

0.50 x 35 = 17.5 = 18

Entering Workchart 3 with 18 daily operations and a distance of 339 feet, we find that the contribution of diesel engine noise is a DNL of 59 dB (see Figure 14).

In order to find the total contribution of the trains to the total DNL, we must also find the noise level produced by the train's cars. Entering Workchart 4 (see Figure 15) with 18 daily operations and a distance of 339 feet, we find the DNL is below 50 on the chart, or more than 10 decibels lower than the noise level produced by the engines. Based on the chart for decibel addition, the combination of the noise from the engines and the cars adds less than 0.5 decibels to the DNL value for the engines alone, 59 dB.

Example 15b: Suppose that a forecast of train operations for Railway 1 indicates that there will still be 35 trains per day, but now 50 percent of the operations will occur at night, the average train will have 4 engines and 75 cars, and the average speed will be 50 mph.

We first find the contribution to DNL made by diesel locomotives by using the following adjustment factors:

- number of engines adjustment: 2
- speed adjustment: 0.60
- day/night adjustment: 2.34

We multiply these adjustments together with the number of trains:

2 X 0.60 X 2.34 X 35 = 98

Entering Workchart 3 (see Figure 14) with 98 daily operations and a distance of 339

Average Train Speed:

If the average train speed is different from 30 mph, find the appropriate adjustment factor from Table 9 and list in column 10 of Worksheet D.

Table 9

Average Speed (mph)	Speed Adjustment Factor
10	3.00
20	1.50
30	1.00
40	0.75
50	0.60
60	0.50
70	0.43

Horns or Whistles:

If the NAL is perpendicular to any point on the track between the whistle posts for the grade crossing, enter the number 10 in column 11, Worksheet D.

Nighttime Adjustment:

Remember to adjust for nightime operations, if different from 0.15 of the total, by selecting the appropriate adjustment factor from Table 5 on page 8. Enter in column 12, Worksheet D.

Multiply the adjustment factors together, times the number of diesel trains per day (you have listed this number previously on line 2a, page 1, of Worksheet D, and should enter this number again in column 13) to obtain the adjusted number of trains per day. Enter the adjusted number of diesel trains per day in column 14. Use this value, in conjunction with the distance from the NAL to the track (line 1, page 1, of Worksheet D), to find from Workchart 3 the DNL produced by diesel locomotives. List in column 15 of Worksheet D.

Railway Cars and Rapid Transit Systems

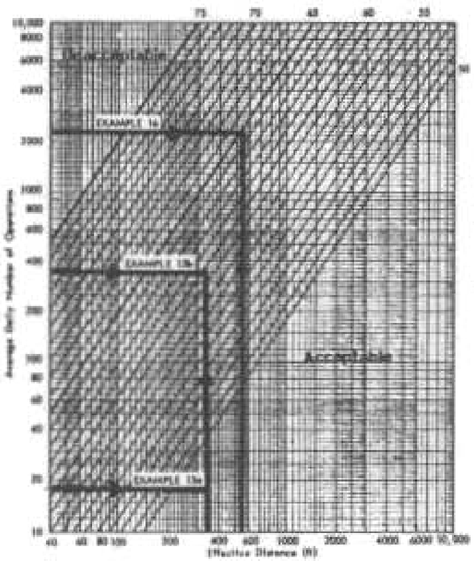
Workchart 4 was derived with the following assumptions:

- A clear line of sight exists between the railway and the NAL.
- There are 50 cars per train.
- The average train speed is 30 mph.
- Nighttime operations are 0.15 of the 24-hour total.
- Rails are welded together.

If the situation meets these conditions, proceed to Workchart 4 for an immediate evaluation of railway car noise. Again, if any of the conditions is different, make the necessary adjustments listed below and then use Workchart 4 for the evaluation.

Figure 15.
Use of Workchart 4 to Evaluate Railway Car Noise

Railroads – Cars and Rapid Transit



Adjustments for Railway Cars and Rapid Transit Trains

Number of Cars:

Divide the average number of cars by 50 and enter this number in column 18 of Workchart D.

Average Speed:

Make this adjustment, if the average speed is not 30 mph, by selecting the appropriate value from Table 10, entering it in column 19 of Worksheet D.

Table 10

Average Speed (mph)	Speed Adjustment Factor
10	0.11
20	0.44
30	1.00
40	1.78
50	2.78
60	4.00
70	5.44
80	7.11
90	9.00
100	11.11

Bolted Rails:

Enter the number 4 in column 20 of Worksheet D.

Nighttime Adjustment:

Enter the appropriate adjustment factor from Table 5 in column 21 of Worksheet D.

feet, we find that the site has an engine noise contribution to DNL of 66 dB.

We next obtain the adjustment factors for the noise produced by the cars:

- number of cars adjustment: 1.50
- speed adjustment: 2.78
- day/night adjustment: 2.34

Multiplying the adjustment factors times the average daily number of trains:

1.5 X 2.78 X 2.34 X 35 = 342

Entering Workchart 4 (see Figure 15) with 342 operations and a distance of 339 feet, we find the contribution of the cars to the DNL is 60 dB. Using Table 1 for combining levels, we find that the 6 dB difference between engine noise at 66 and car noise at 60 gives a combined DNL of 67 dB for these trains.

Example 16: The distance from NAL number 2 to Railroad Number 2 is 550 feet; there are 100 operations per day, of which 30 percent occur at night. A clear line of sight exists between the site and the railroad, and no horns or whistles are used nearby. An average train on this track uses 4 engines, has 100 cars, the average speed is 40 miles per hour, and the track has bolted, not welded, rails.

We first find the adjustment factors for the diesel engines:

- number of engines adjustment: 2
- speed adjustment: 0.75
- day/night adjustment: 1.57

Multiplying the adjustments together, times the number of trains:

2 X 0.75 X 1.57 X 100 = 236

Entering Workchart 3 (see Figure 14) with 236 operations at a distance of 550 feet, we find the DNL contribution from engine noise to be 67 dB.

Next we find the adjustment factors for the railroad cars:

- number of cars adjustment: 2
- speed adjustment: 1.78
- bolted track adjustment: 4
- day/night adjustment: 1.57

Multiplying the adjustments together, times the number of trains:

2 X 1.78 X 4 X 1.57 X 100 = 2236

Entering Workchart 4 (see Figure 15) with

(Continued next page)

Figure 16.
Sketch Showing Dimensions for Example 16

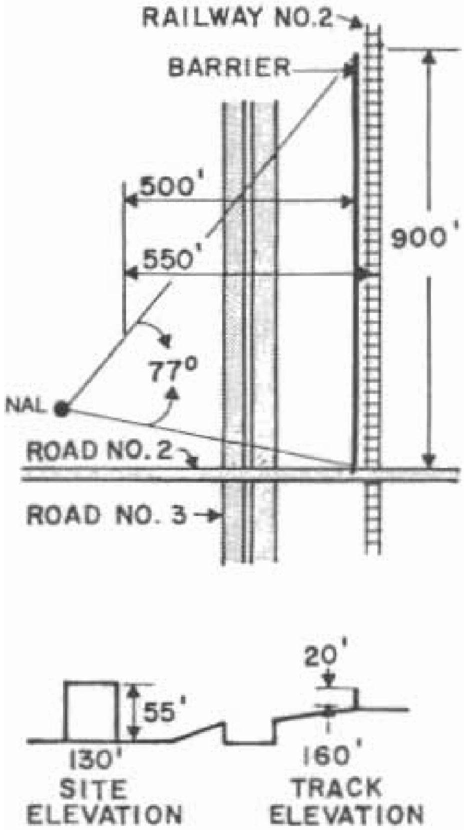


Figure 17.
Use of Workchart 6 in Example 16

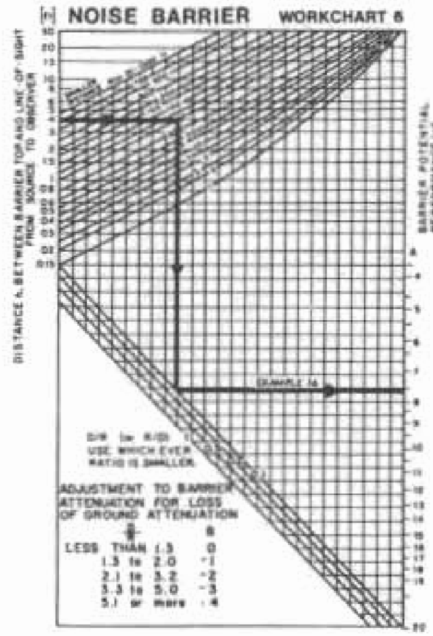
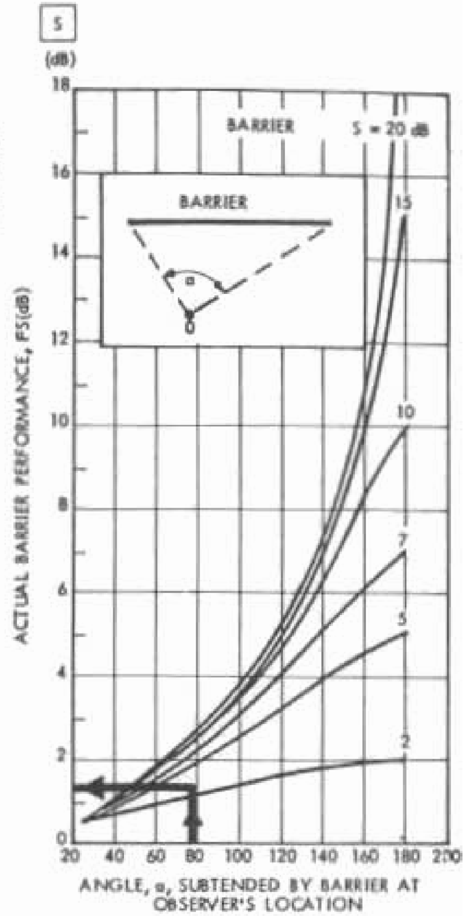


Figure 18.
Use of Workchart 7 in Example 16



2236 operations at a distance of 550 feet, we find the DNL contribution from the railroad cars to be 65 dB. Combining the engine sound levels with the car sound levels we find the total DNL from the trains to be 69 dB.

It would be possible to erect a 20-foot noise barrier, running parallel to the track at a distance of 50 feet; it could start at Road Number 2 and run 900 feet north toward the airport, as shown in Figure 16. Both the railroad track and the ground level at the barrier location are at an elevation of 160 feet. Thus, we have the following values with which to calculate the potential reduction in engine noise (using Workchart 5). (Because the distances involved are so unequal, this situation does not lend itself to direct scaling of the distances.)

H = 180 feet (20' above the ground)

S = 175 feet (15' above the track, see page 19)

O = 285 feet (from Example 11 in the section on roadway noise)

R' = 50 feet

D' = 500 feet

We find from Worksheet 5 that the values of R and D are no different (within the accuracy of the calculation) from R' and D', a situation that will always occur when the differences in elevation are so much smaller than the distances from the site to the noise source. The value of h is 4 feet; R/D = 0.1

We can now use these numbers to enter Workchart 6 to find the *potential* barrier performance (that is, the barrier adjustment factor that would apply in the case of an infinitely long barrier). Entering Workchart 6 at h = 4 feet, with R/D = 0.1, we find the basic attenuation of the barrier to be 7.5 dB. However, with D/R = 10, we find from the table of loss-of-ground-effect attenuation that we must subtract 4 dB from the 7.5, or a net effect of 3.5 dB. However, the situation is even worse, since the barrier is finite in length.

To find the actual attenuation for this *finite* barrier, we must first find the angle subtended by the barrier to the NAL. Referring to Figure 16, we draw lines from the NAL each end of the barrier. With

References

1. D.E. Bishop, A.P. Hays, "Handbook for Developing Noise Exposure Contours for General Aviation Airports," FAA-AS-75-1, December 1975 (NTIS No. AD-A023429).

2. D.E. Bishop, et al., "Calculation of Day-Night Levels Resulting From Civil Aircraft Operations," BBN Report 3157 for Environmental Protection Agency, March 1976 (NTIS No. PB 266 165).

3. B.A. Kugler, D.E. Commins, W.J. Galloway, "Highway Noise – A Design Guide for Prediction and Control," NCHRP Report 174, Transportation Research Board, National Research Council, 1976.

4. T.J. Schultz, W.J. Galloway, "Noise Assessment Guidelines – Technical Background," Office of Policy Development and Research, U.S. Department of Housing and Urban Development," 1980.

5. M.A. Simpson, "Noise Barrier Design Handbook," FHWA-RD-76-58, Federal Highway Administration, February 1976 (NTIS No. PB 266 378).

a protractor we measure the angle between the two lines to be 77 degrees. Locate the curve on Workchart 7 corresponding to the potential barrier attenuation of 3.5 dB; it lies midway between the two lowest curves (see Figure 18). The point on this curve corresponding to a subtended angle of 77 degrees indicates that the actual barrier performance would be only 1.5 dB. With only 1.5 dB of attenuation, the barrier is clearly not cost-effective. In order to achieve a usable attenuation from the barrier, it would have to be extended beyond the other side of Road Number 2 to obtain a larger subtended angle. This extension, however, would still not be cost-effective unless the height of the barrier were increased substantially.

Summary of Adjustment Factors

Combination of Sound Levels

Table 1

Difference in Sound Level	Add to Larger Level
0	3.0
1	2.5
2	2.1
3	1.8
4	1.5
5	1.2
6	1.0
7	0.8
8	0.6
9	0.5
10	0.4
12	0.3
14	0.2
16	0.1
greater than 16	0.

Aircraft

Table 2 DNL Outside 65 dB Contour

D1 = distance from 65 dB contour to flight path
D2 = distance from site to flight path

D2 D1	DNL dB
1.0	65
1.12	64
1.26	63
1.41	62
1.58	61
1.78	60
2.00	59
2.24	58
2.51	57
2.82	56
3.16	55

Automobile Traffic

Table 3 Stop-and-go

Distance from Site to Stop Sign feet	Automobile Stop-and-go Adjustment Factor
0	0.10
100	0.25
200	0.40
300	0.55
400	0.70
500	0.85
600	1.00

Table 4 Average Traffic Speed

Average Traffic Speed	Adjustment Factor
20 (mph)	0.13
25	0.21
30	0.30
35	0.40
40	0.53
45	0.67
50	0.83
55	1.00
60	1.19
65	1.40
70	1.62

Table 5 Nighttime (applies to all sources)

Nighttime Fraction of ADT	Nighttime Adjustment Factor
0	0.43
0.01	0.46
0.02	0.50
0.05	0.62
0.10	0.81
0.15	1.00
0.20	1.19
0.25	1.38
0.30	1.57
0.35	1.78
0.40	1.96
0.45	2.15
0.50	2.34

Medium Trucks

(less than 26,000 pounds, greater than 10,000 pounds)

Multiply adjusted automobile traffic by 10.

Heavy Trucks

Table 6 Road Gradient

Percent of Adjustment Gradient Factor	
2	1.4
3	1.7
4	2.0
5	2.2
6 or more	2.5

Table 7 Average Speed

Average Traffic Speed (mph)	Truck Speed Adjustment Factor
50 or less	0.81
55	1.00
60	1.17
65	1.38

Table 8 Stop-and-go

Heavy Truck Traffic Volume per Day	Heavy Truck Stop-and-Go Adjustment Factor
Less than 1200	1.8
1201 to 2400	2.0
2401 to 4800	2.3
4801 to 9600	2.8
9601 to 19,200	3.8
More than 19,200	4.5

Railroads - Diesel Engines

Number of Engines per Train
The number of engines divided by 2.

Table 9 Average Train Speed

Average Speed (mph)	Speed Adjustment Factor
10	3.00
20	1.50
30	1.00
40	0.75
50	0.60
60	0.50
70	0.43

Whistles or horns
Multiply number of trains by 10.

Railroads - Cars and Rapid Transit

Numbers of cars.
Number of cars per train divided by 50.

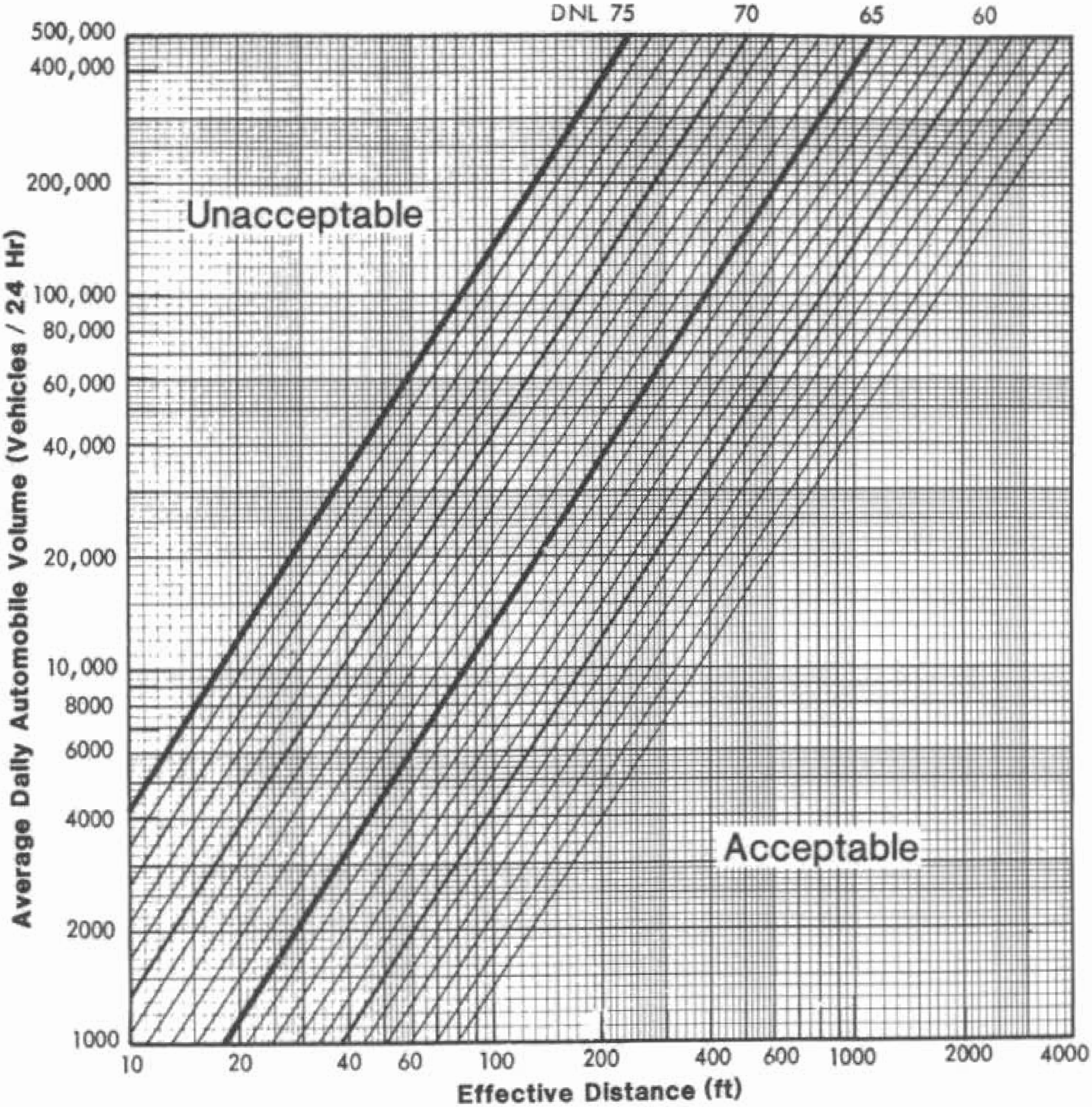
Table 10 Average Train Speed

Average Speed (mph)	Speed Adjustment Factor
10	0.11
20	0.44
30	1.00
40	1.78
50	2.78
60	4.00
70	5.44
80	7.11
90	9.00
100	11.11

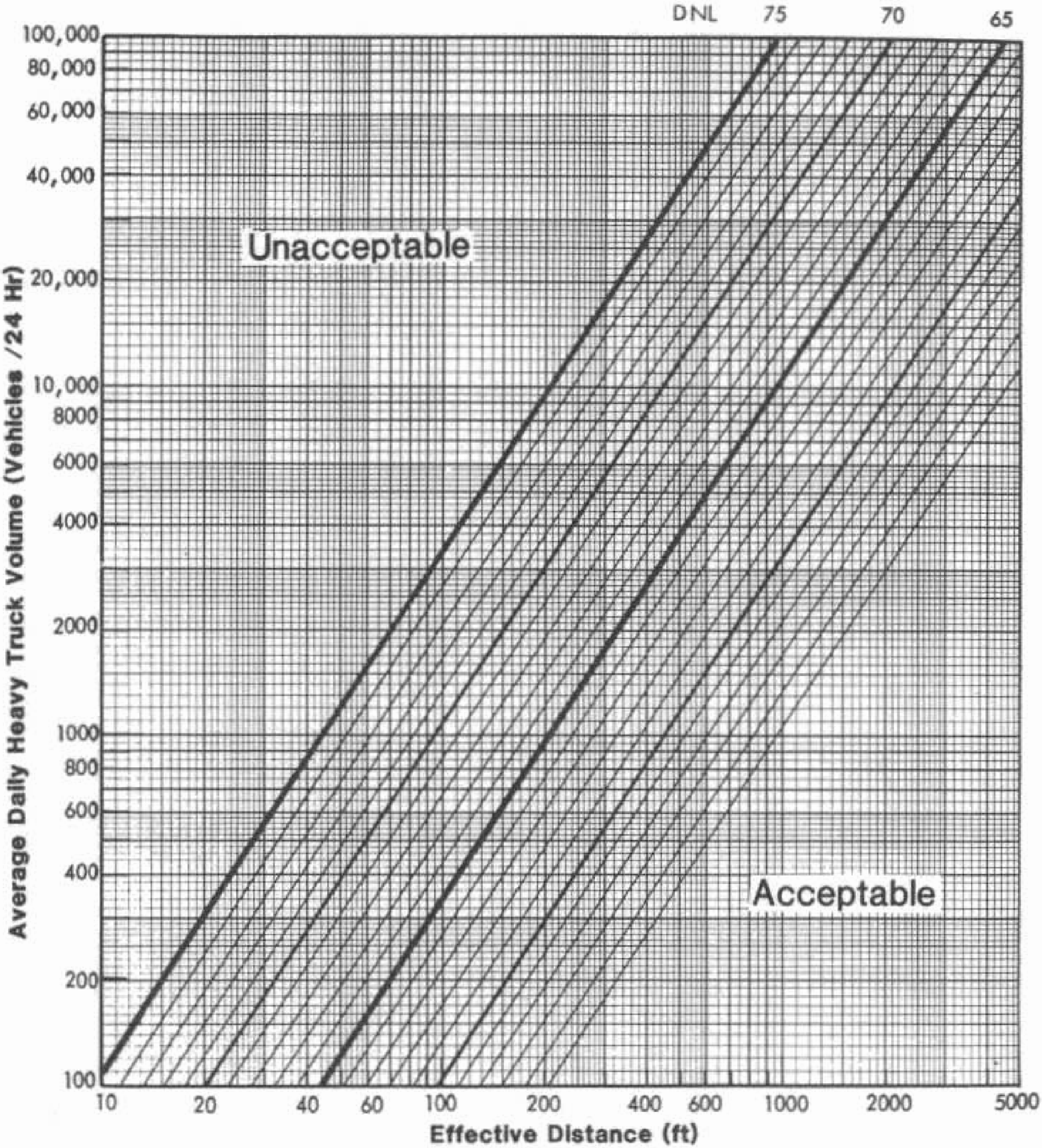
Bolted Rails
Multiply number of trains by 4.

Whistles or Horns
Multiply number of trains by 100.

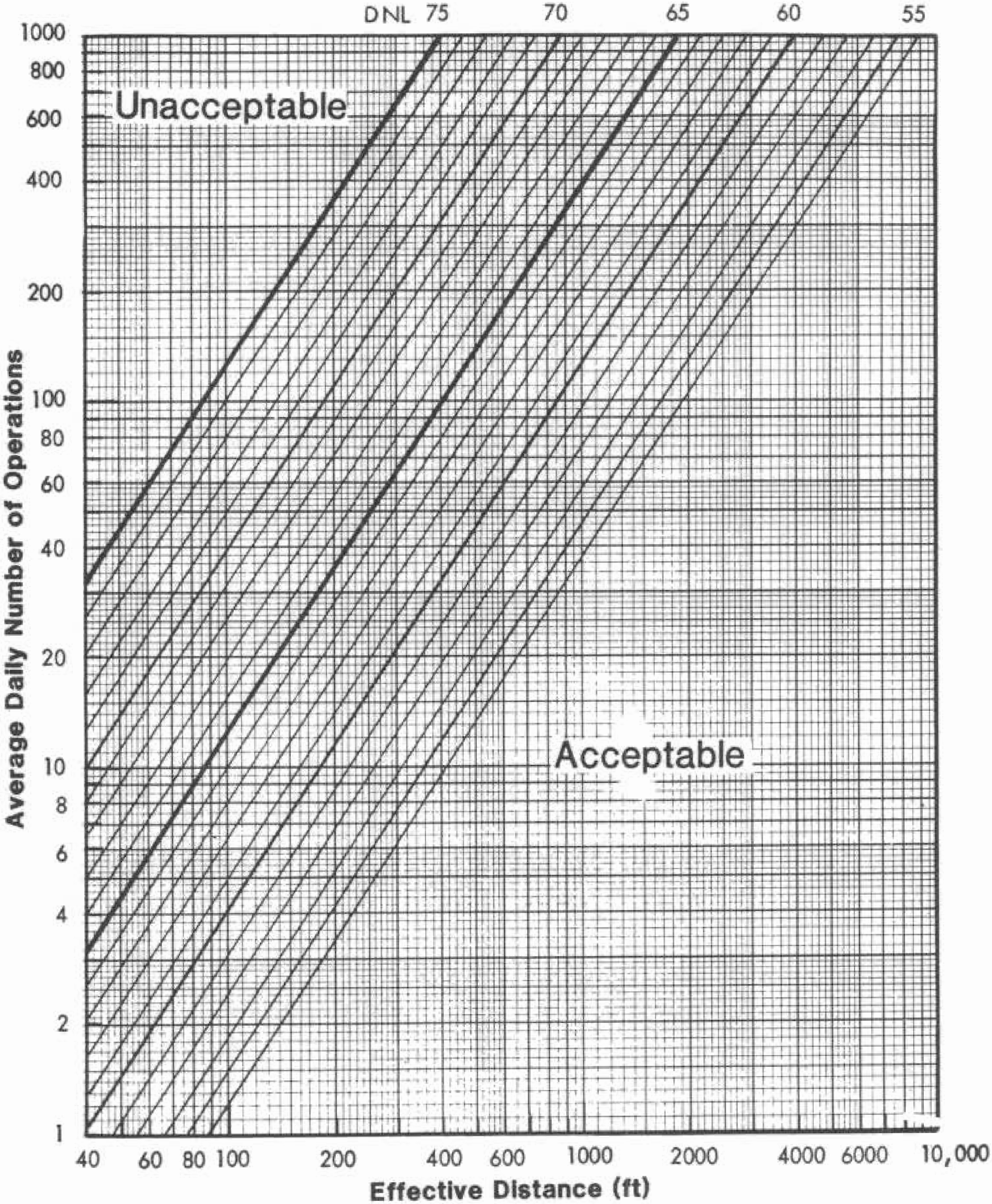
Workchart 1
Autos (55 mph)



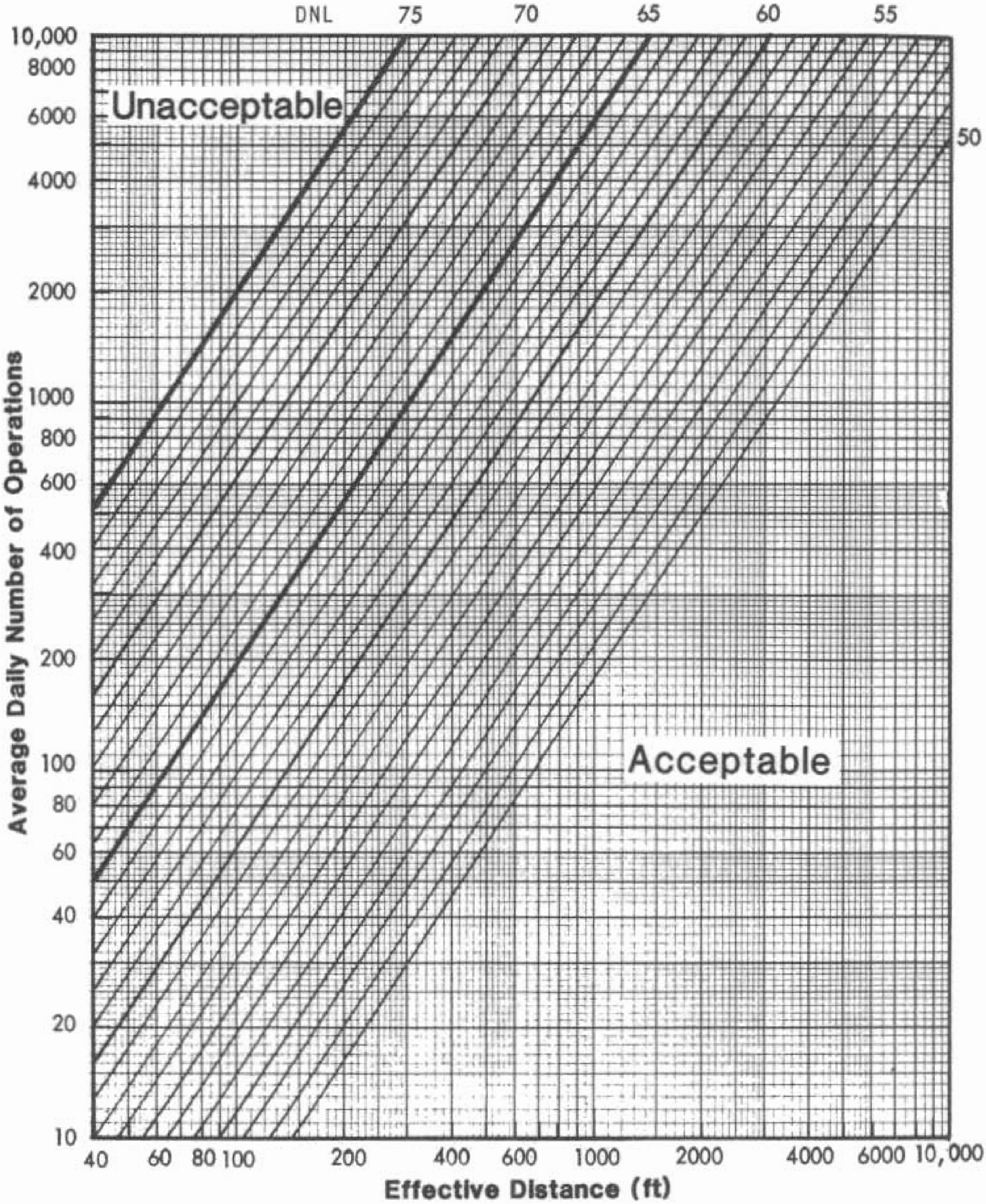
Workchart 2
Heavy Trucks (55 mph)



Workchart 3
Railroads - Diesel Locomotives



Workchart 4
Railroads - Cars and Rapid Transit



22

Workchart 5
Noise Barrier

To find R, D and h from Site Elevations and Distances

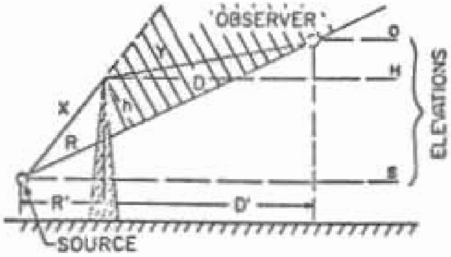
Fill out the following worksheet (all quantities are in feet):

Enter the values for:

H= ____________ R'= ____________

S= ____________ D'= ____________

O= ____________

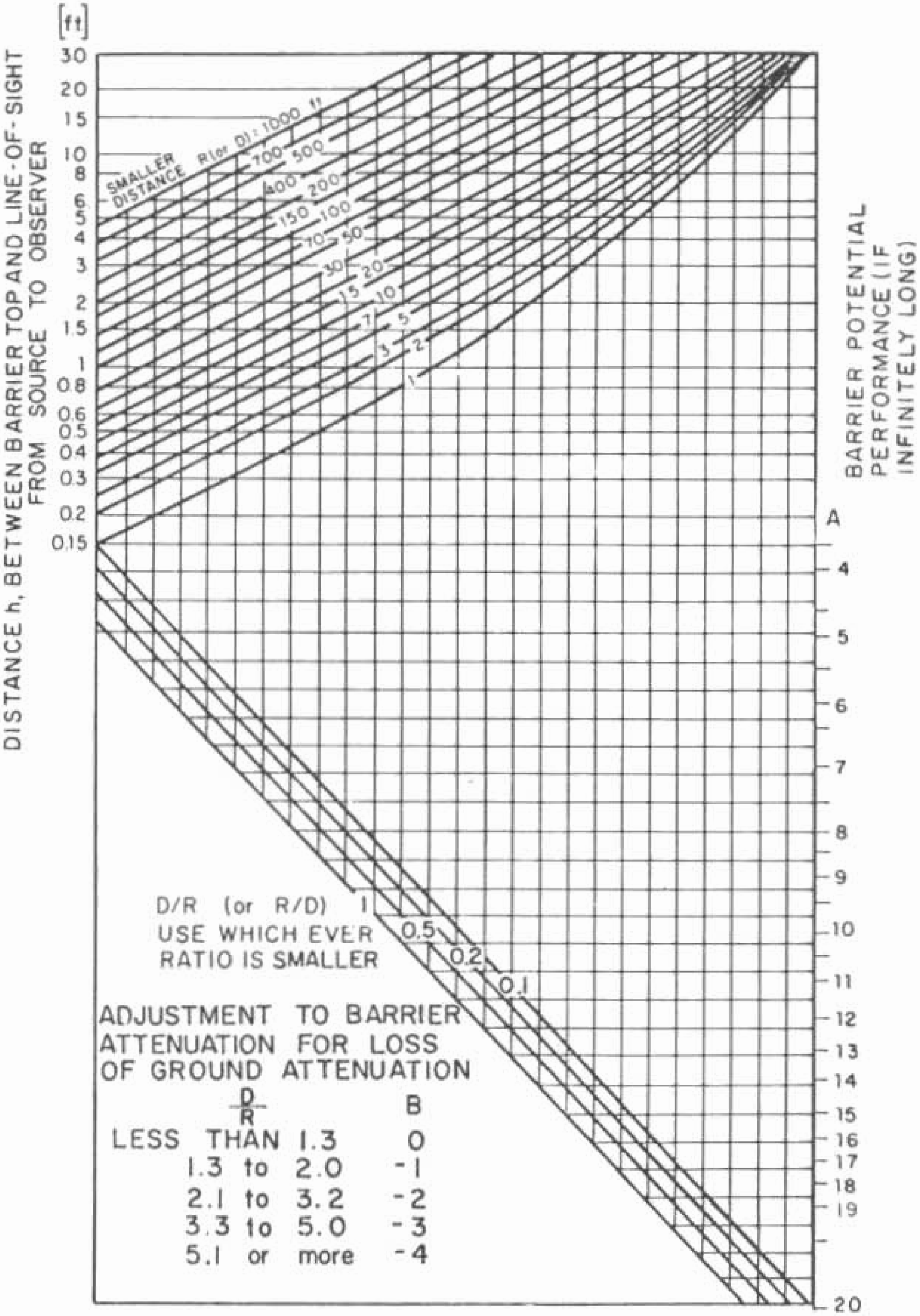


1. Elevation of barrier top minus elevation of source	[H]	−	[S]	=	[1]	
2. Elevation of observer minus elevation of source	[O]	−	[S]	=	[2]	
3. Map distance between source and observer (R' + D')					[3]	
4. Map distance between barrier and source (R')					[4]	
5. Line 2 divided by line 3	[2]	÷	[3]	=	[5]	
6. Square the quantity on line 5 (i.e., multiply it by itself); always positive	[5]	×	[5]	=	[6]	
7. 40% of line 6	[0.4]	×	[6]	=	[7]	
8. One minus line 7	[1.0]	−	[7]	=	[8]	
9. Line 5 times line 4 (will be negative if line 2 is negative)	[5]	×	[4]	=	[9]	
10. Line 1 minus line 9	[1]	−	[9]	=	[10]	
11. Line 10 times line 8	[10]	×	[8]	=	[11]	= h
12. Line 5 times line 10	[5]	×	[10]	=	[12]	
13. Line 4 divided by line 8	[4]	÷	[8]	=	[13]	
14. Line 13 plus line 12	[13]	+	[12]	=	[14]	= R
15. Line 3 minus line 4	[3]	−	[4]	=	[15]	
16. Line 15 divided by line 8	[15]	÷	[8]	=	[16]	
17. Line 16 minus line 12	[16]	−	[12]	=	[17]	= D

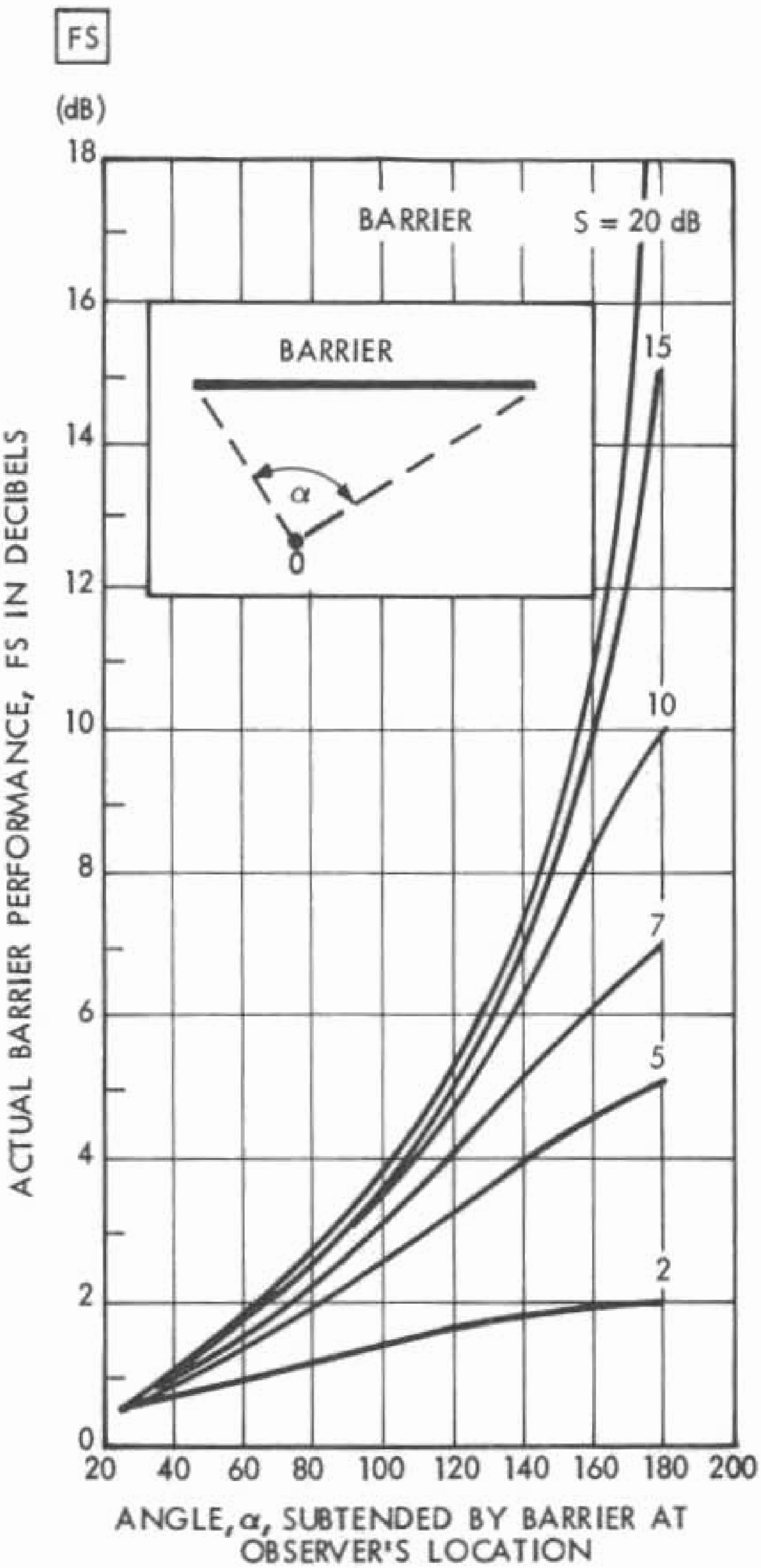
[**Note:** the value on line 2 may be negative, in which case so will the values on lines 5,9, and 12; line 1 may also be negative. Remember, then, in lines 10, 14, and 17, that adding a negative number is the same as subtracting: $x+(-y)=x-y$. And subtracting a negative number is like adding: $x-(-y)=x+y$.

Round off R and D to nearest integer, h to one decimal place.

Workchart 6
Noise Barrier



Workchart 7



Correction to be applied to barrier potential in order to find the actual performance of the barrier of the same construction but of finite length.

Worksheet A
Site Evaluation

Site Location

Program

Project Name

Locality

File Number

Sponsor's Name | Phone

Street Address | City, State

	Acceptability Category	DNL	Predicted for Operations in Year
1. Roadway Noise	______	______	______
2. Aircraft Noise	______	______	______
3. Railway Noise	______	______	______

Value of DNL for all noise sources: (see page 3 for combination procedure) ______

Final Site Evaluation (circle one)

Acceptable

Normally Unacceptable

Unacceptable

Signature ______ Date ______

Clip this worksheet to the top of a package containing Worksheets B-E and Workcharts 1-7 that are used in the site evaluations

Worksheet B
Aircraft Noise

List all airports within 15 miles of the site:

1. ____________________

2. ____________________

3. ____________________

Necessary Information:	**Airport 1**	**Airport 2**	**Airport 3**
1. Are DNL, NEF or CNR contours available? (yes/no)			
2. Any supersonic aircraft operations? (yes/no)			
3. Estimating approximate contours from Figure 3:			
a. number of nighttime jet operations			
b. number of daytime jet operations			
c. effective number of operations (10 times a + b)			
d. distance A for 65 dB			
70dB			
75 dB			
e. distance B for 65 dB			
70 dB			
75 dB			
4. Estimating DNL from Table 2:			
a. distance from 65 dB contour to flight path, D^1			
b. distance from NAL to flight path, D^2			
c. D^2 divided by D^1			
d. DNL			
5. Operations projected for what year?			
6. Total DNL from all airports			

Signed ____________________ Date ____________________

List all major roads within 1000 feet of the site:

1. ____

2. ____

3. ____

4. ____

Necessary Information	**Road 1**	**Road 2**	**Road 3**	**Road 4**
1. Distance in feet from the NAL to the edge of the road				
a. nearest lane	____	____	____	____
b. farthest lane	____	____	____	____
c. average (effective distance)	____	____	____	____
2. Distance to stop sign	____	____	____	____
3. Road gradient in percent	____	____	____	____
4. Average speed in mph				
a. Automobiles	____	____	____	____
b. heavy trucks - uphill	____	____	____	____
c. heavy trucks - downhill	____	____	____	____
5. 24 hour average number of automobiles and medium trucks in both directions (ADT)				
a. automobiles	____	____	____	____
b. medium trucks	____	____	____	____
c. effective ADT (a + (10xb))	____	____	____	____
6. 24 hour average number of heavy trucks				
a. uphill	____	____	____	____
b. downhill	____	____	____	____
c. total	____	____	____	____
7. Fraction of nighttime traffic (10 p.m. to 7 a.m.)	____	____	____	____
8. Traffic projected for what year?	____	____	____	____

Adjustments for Automobile Traffic

	9 Stop and-go Table 3	10 Average Speed Table 4	11 Night-Time Table 5	12 Auto ADT (line 5c)	13 Adjusted Auto ADT	14 DNL (Workchart 1)	15 Barrier Attenuation	16 Partial DNL
Road No. 1		X	X	X	=		–	=
Road No. 2		X	X	x	=		–	=
Road No. 3		X	X	X	=		–	=
Road No. 4		X	X	X	=		–	=

Adjustments for Heavy Truck Traffic

		17 Gradient Table 6	18 Average Speed Table 7	19 Truck $\frac{ADT}{2}$	20	21	22 Stop and-go Table 8	23 Night-Time Table 5	24 Adjusted Truck ADT	25 DNL (Work-chart 2)	26 Barrier Attn.	27 Partial DNL
Road No. 1	Uphill		X	X	=							
						Add	X	X	=		–	=
	Downhill			X	=							
Road No. 2	Uphill		X	X	=							
						Add	X	X	=		–	=
	Downhill			X	=							
Road No. 3	Uphill		X	X	=							
						Add	X	X	=		–	=
	Downhill			X	=							
Road No. 4	Uphill		X	X	=							
						Add	X	X	=		–	=
	Downhill			X	=							

Combined Automobile & Heavy Truck DNL

Road No. 1 ________ Road No. 2 ________ Road No. 3 ________ Road No. 4 ________ Total DNL for All Roads ____________

Signature ____ Date ____________________

List All Railways within 3000 feet of the site:

1. ______________________________

2. ______________________________

3. ______________________________

Necessary Information:	Railway No. 1	Railway No. 2	Railway No. 3
1. Distance in feet from the NAL to the railway track:	______	______	______
2. Number of trains in 24 hours:			
a. diesel	______	______	______
b. electrified	______	______	______
3. Fraction of operations occuring at night (10 p.m. – 7 a.m.):	______	______	______
4. Number of diesel locomotives per train:	______	______	______
5. Number of rail cars per train:			
a. diesel trains	______	______	______
b. electrified trains	______	______	______
6. Average train speed:	______	______	______
7. Is track welded or bolted?	______	______	______
8. Are whistles or horns required for grade crossings?	______	______	______

Adjustments for Diesel Locomotives

	9 No. of Locomotives / 2		10 Average Speed Table 9		11 Horns (enter 10)		12 Night-time Table 5		13 No. of Trains (line 2a)		14 Adj. No. of Opns.	15 DNL Workchart 3		16 Barrier Attn.		17 Partial DNL
Railway No. 1	____	X	____	X	____	X	____	X	____	=	____	____	–	____	=	____
Railway No. 2	____	X	____	X	____	X	____	X	____	=	____	____	–	____	=	____
Railway No. 3	____	X	____	X	____	X	____	X	____	=	____	____	–	____	=	____

Adjustments for Railway Cars or Rapid Transit Trains

	18 Number of cars / 50		19 Average Speed Table 10		20 Bolted Rails (enter 4)		21 Night-time Table 5		22 No. of Trains (Line 2a or 2b)		23 Adj. No. of Opns.	24 DNL Work-chart 4		25 Barrier Attn.		26 Partial DNL
Railway No. 1	____	X	____	X	____	X	____	X	____	=	____	____	–	____	=	____
Railway No. 2	____	X	____	X	____	X	____	X	____	=	____	____	–	____	=	____
Railway No. 3	____	X	____	X	____	X	____	X	____	=	____	____	–	____	=	____

Combined Locomotive and Railway Car DNL

Railway No. 1 ________ Railway No. 2 ________ Railway No. 3 ________ Total DNL for all Railways ________

Signature ______________________________ Date ______________

Chapter 6

A Workbook for the Noise Assessment Guidelines

Introduction

The following problems were prepared to give you the opportunity to practice the calculations and procedures described in the *Noise Assessment Guidelines*. Because it is so rarely used, we have not included any problems dealing with the aircraft noise procedure.

We have not reproduced the charts or tables from the *Guidelines* so you will need to have it at hand to do the problems.

Noise Assessment Guidelines Workbook

Problems

Problems 1 Through 7: Combining Sound Levels in Decibels

Calculate the Combined Sound Level for the Following Sets of Individual Levels:

1. 67 LDN
   61 LDN
   ______ Combined Level

2. 63 LDN
   63 LDN
   ______ Combined Level

3. 51 LDN
   68 LDN
   ______ Combined Level

4. 62 LDN
   65 LDN
   ______ Combined Level

5. 67 LDN
   72 LDN
   ______ Combined Level

6. 59 LDN
   63 LDN
   71 LDN
   ______ Combined Level

7. 73 LDN
   72 LDN
   61 LDN
   67 LDN
   ______ Combined Level

Problems 8 and 9: Calculating Effective Distance

Calculate the Effective Distances for the Following Roads:

8.	Distance in Feet from NAL to:	
	Near Edge of Nearest Lane	22 Feet
	Far Edge of Farthest Lane	76 Feet
	Effective Distance	______
9.	Distance in Feet from NAL to:	
	Near Edge of Nearest Lane	60 Feet
	Far Edge of Farthest Lane	84 Feet
	Effective Distance	______

Problems 10 Through 15: Adjustment Factors

List The Adjustment Factors Necessary for Each of the Following Situations and the Numerical Value for Each Adjustment Factor.

10. A Roadway Where the Road Gradient Is 1%, the Average Speed for Both Autos and Trucks Is 30 MPH and the Fraction of Nighttime Traffic Is 10%.

    Adjustment Factors Needed: ______________________

    ____

    ____

    Value of Adjustment Factors: ______________________

    ____

    ____

11. A Roadway Where There Is A Stop Sign 400 Feet from the NAL. The Gradient Is 1%, the Average Speed for Autos Is 45 MPH (There Are No Trucks) and the Fraction of Nighttime Traffic Is 15%.

    Adjustment Factors Needed: ______________________

    ____

    ____

    Value of Adjustment Factors: ______________________

    ____

    ____

12. A Roadway Where the Road Gradient Is 2%, the Average Speed for Autos Is 50 MPH and for Trucks (Both Uphill and Downhill) Is 50 MPH and the Fraction of Nighttime Traffic Is 10%.

Adjustment Factors Needed: ______________________

____

____

Value of Adjustment Factors: ______________________

____

13. A Railroad Where the Fraction of Operations Occurring at Night Is 30%, the Average Train Speed Is 40 MPH, the Track Is Bolted and There Are No Whistle Or Horns Required for Grade Crossings.

Adjustment Factors Needed: ______________________

____

____

Value of Adjustment Factors: ______________________

____

____

14. A Railroad Where the Fraction of Operations Occurring at Night Is 5%, the Average Train Speed Is 10 MPH, the Tracks Are Welded and There Are No Whistles Or Horns Required for Grade Crossing.

Adjustment Factors Needed: ______________________

____

____

Value of Adjustment Factors: ______________________

____

____

15. A Railroad Where the Fraction of Operations Occurring at Night Is 20%, the Average Train Speed Is 30 MPH, the Track Is Bolted and No Whistles or Horns Are Required for Grade Crossings.

Adjustment Factors Needed: ______________________

____

____

Value of Adjustment Factors: ______________________

____

____

Problems 16 Through 21: Some Basic Problems

Calculate the Combined Noise Levels for Each of the Following Situations:

16. A Roadway Where the distance in Feet from the NAL to the Near Edge of the Nearest Lane Is 310 Feet, the Distance to the Far Edge of the Farthest Lane Is 358 Feet. There Is A Stop Sign 400 Feet from the NAL. The Gradient Is 1%. The Average Number of Automobiles Is 17,000, the 24 Hour Average Number of Medium Trucks Is 1,500, the 24 Hour Average Number of Heavy Trucks Is 400 Total. The Fraction of Nighttime Traffic Is 20%.

    The Combined Noise Level for This Roadway Is ______________________________.

17. A Site Exposed to Noise from Two Roads. For Roadway Number 1 the Distance in Feet from the NAL to the Near Edge of the Nearest Lane Is 125 Feet, the Distance to the Far Edge of the Farthest Lane Is 233 Feet. There Is A Stop Sign 250 Feet from the NAL. The Gradient Is 3%. The Average Speed for Both Autos and Trucks Is 30 MPH.

    The 24 Hour Average Number of Autos Is 22,000, the 24 Hour Average Number of Medium Trucks Is 2,000. The 24 Hour Average Number of Heavy Trucks Is 950 Total. The Fraction of Nighttime Traffic Is 10%.

    For Roadway Number 2, the Distance to the Near Edge of the Nearest Lane Is 45 Feet, the Distance to the Far Edge of the Farthest Lane Is 93 Feet. There Is A Stop Sign 100 Feet from the NAL and the Gradient Is 1%. The Average Speed for Both Autos and Heavy Trucks Is 30 MPH. The 24 Hour Average Number of Automobiles Is 14,000, for Medium Trucks 700, and for Heavy Trucks 600 Total. The Fraction of Nighttime Traffic Is 20%.

    The Combined Noise Level for This Site Is ______________________________

18. A Site Exposed to Noise from Two Railroads. For Railroad 1, the Distance in Feet from the NAL to the Railway Track Is 150 Feet. There Are 35 Diesel Trains Every 24 Hours, No Electrified Trains. The Fraction of Operations Occurring at Night Is 25%. There Are 3 Diesel Locomotives Per Train and 70 Cars Per Train. The Average Speed Is 30 MPH and the Track Is Bolted. No Whistles Or Horns Are Used.

    For Railroad 2, the Distance in Feet from the NAL to the Railway Track Is 310 Feet. There Are 20 Diesel and 2 Electrified Trains Each 24 Hours. The Fraction of Operations Occurring at Night Is 15%. There Are 2 Locomotives Per Diesel Train and 45 Cars for Each Diesel Train and 15 Cars Per Electrified Train. The Average Train Speed Is 40 MPH and the Track Is Bolted. No Horns Or Whistles Are Used.

    The Combined Noise Level for This Site Is ______________________________.

19. A Site Exposed to Noise from Two Railroads. For Railroad 1, the Distance in Feet from the NAL to the Railway Track Is 75 Feet. There Are 34 Diesel Trains Every 24 Hours, No Electrified Trains. Twenty Percent of the Operations Occur at Night. There Are 5 Locomotives Per Train and 75 Cars Per Train. The Average Train Speed Is 35 MPH and the Track Is Welded. No Horns Or Whistles.

    For Railway 2, the Distance in Feet from the NAL to the Railway Track Is 120 Feet. There Are 12 Diesel Trains in 24 Hours, No Electrified Trains. Twenty-Five Percent of the Operations Occur at Night. There Are 4 Locomotives Per Train and 40 Cars Per Train. The Average Train Speed Is 20 MPH and the Track Is Bolted. No Horns Or Whistles Are Used.

    The Combined Noise Level for This Site Is ______________________________

20. A Site Exposed to Noise from Three Roads. For Road 1, the Distance in Feet from the NAL to the Near Edge of the Nearest Lane Is 100 Feet, to the Far Edge of the Farthest Lane, 208 Feet. There Is No Stop Sign and the Gradient Is 1%. The Average Speed for Autos Is 55 MPH. (There Are No Trucks Allowed On This Road.) The 24 Hour Average Number of Autos Is 40,000. The Fraction of Nighttime Traffic Is 15%.

    For Road 2, the Distance from the NAL to the Near Edge of the Nearest Lane Is 45 Feet, to the Far Edge of the Farthest Lane 75 Feet. There Is A Stop Sign 175 Feet from the NAL and the Road Gradient Is 4%. The average Speed for Both Autos and Trucks Is 40 MPH. The 24 Hour Average Number of Autos Is 15,000, for Medium Trucks 900 and for Heavy Trucks 320 Total. The Fraction of Nighttime Traffic Is 20%.

    For Road 3, the Distance from the NAL to the Near Edge of the Nearest Lane Is 52 Feet, to the Far Edge of the Farthest Lane 92 Feet. There Is A Stop Sign 400 Feet from the NAL and the Gradient Is 1%. The Average Speed for Both Autos and Trucks Is 25 MPH. The 24 Hour Average Number of Autos Is 5,000, for Medium Trucks 1,050 and for Heavy Trucks 175 Total. The Fraction of Nighttime Traffic Is 20%.

    The Combined Noise Level for This Site Is ______________________________.

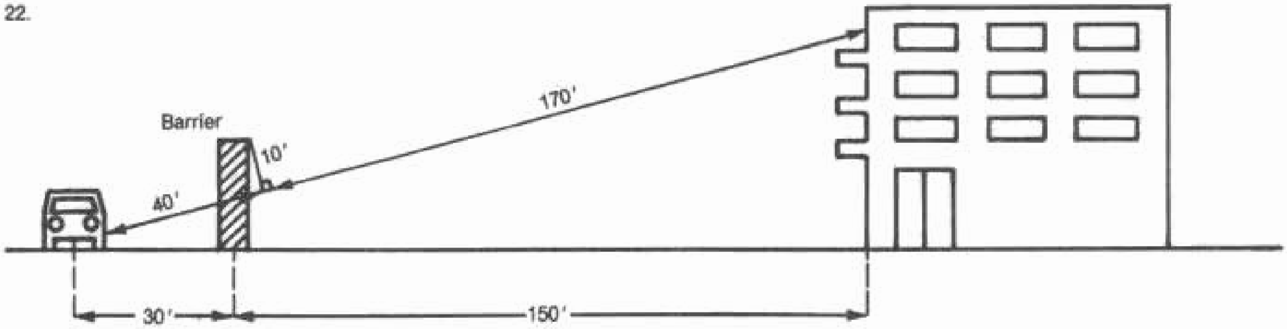
21. A Site Exposed to Noise from A Railroad. The Distance from the NAL to the Railroad Is 110 Feet. There Are 30 Diesel Trains Every 24 Hours, No Electrified Trains. Twenty Percent of the Operations Occur at Night. There Are 3 Locomotives Per Train and 50 Cars Per Train. The Average Train Speed Is 30 MPH, the Track Is Bolted and There Is A Grade Crossing Where Horns and Whistles Are Used 100 Feet from the NAL.

The Combined Noise Level at This Site Is ______________________.

Problems 22 Through 24: Barriers - Identifying the Values for H, R, R′, D and D′

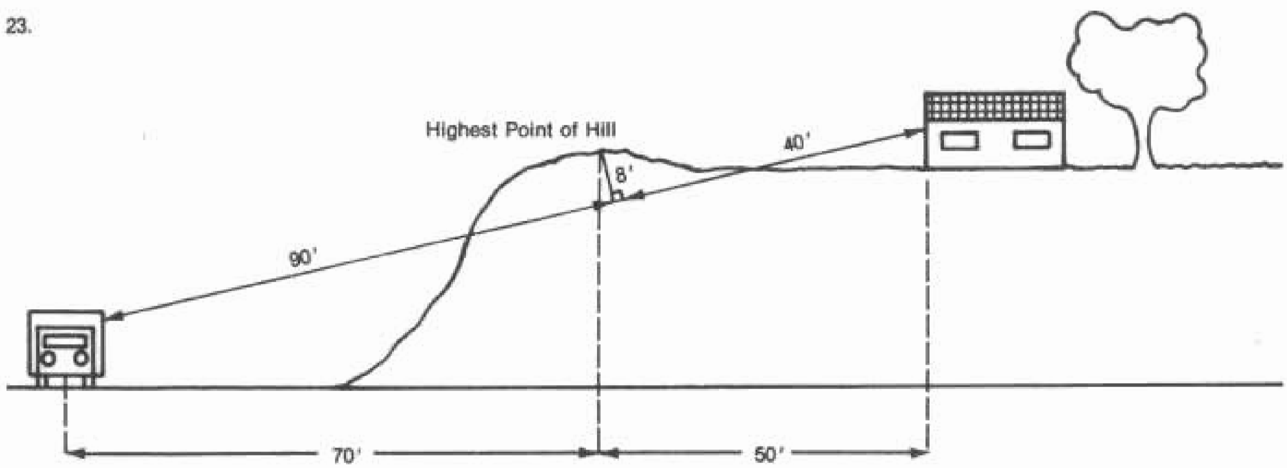
Identify the Values for H, R, R′, D and D′ for Each of the Following Barriers:

22.



H = ________, R = ________, R′ = ________ D = ________ and D′ = ________

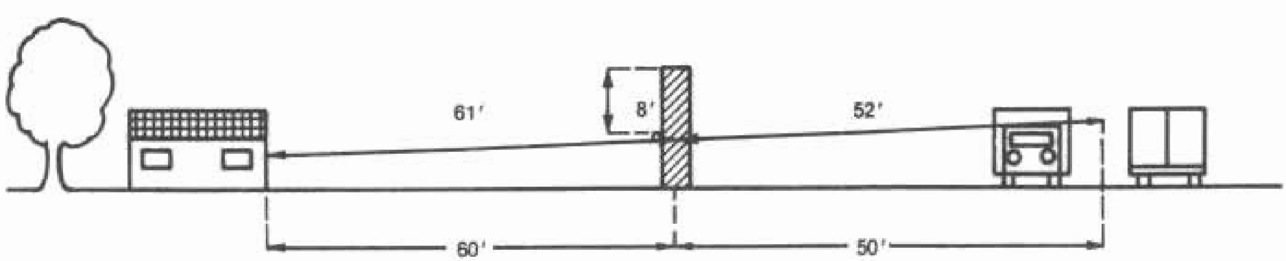
23.



H = ________, R = ________, R′ = ________, D = ________ and D′ = ________

Barrier	40′	10′	170′	90′	70′
Highest Point of Hill	30′	150′		8′	50′
				40′	

24.



H = ________, R = ________, R′ ________, D = ________ and D′ ________

Problems 25 Through 27: Barrier Calculations Using Workcharts 6 and 7.

Using Workcharts 6 and 7 Only, Calculate the Noise Attenuation Provided by the Barriers Illustrated in Problems 22 Through 24. Additional Data on the Angles Subtended by the Ends of the Barriers and the NAL for Each Location Is Provided.

25. Calculate the Noise Attenuation Provided by the Barrier Described in Problem 22. The Angle Subtended by the Ends of the Barrier and the NAL Is 150 Degrees.

    The Noise Attenuation Provided Is ______________________________ Decibels.

26. Calculate the Noise Attenuation Provided by the Barrier Described in Problem 23. The Angle Subtended by the Ends of the Barrier and the NAL Is 90 Degrees.

    The Noise Attenuation Provided Is ______________________________ Decibels.

27. Calculate the Noise Attenuation Provided by the Barrier Described in Problem 24. The Angle Subtended by the Ends of the Barrier and the NAL Is 130 Degrees.

    The Noise Attenuation Provided Is ______________________________ Decibels.

Problems 28 Through 30: Barrier Calculations Using Workcharts 5, 6 and 7

Calculate the Attenuation Provided By the Barriers in the Following Situations. Use Workcharts 5, 6 and 7.

28. A Two Story Building Is Exposed to Noise Levels of 68 LDN from Automobiles. The Barrier Is 15 Feet High and Is Located 40 Feet from the Source and 20 Feet from the Building. The Source, Barrier, and Building Are All On Level Ground. The Angle Subtended by the Ends of the Barrier and the Noise Assessment Location Is 110 Degrees.

    The Noise Attenuation Provided by This Barrier Is ____________________ Decibels.

    Is This Sufficient? ____

29. A Three Story Building Is Exposed to A Noise Level of 72 LDN from Diesel Locomotives and 60 LDN from Railroad Cars. The Barrier Is 12 Feet High and Is Located 40 Feet from the Source and 85 Feet from the Building. The Barrier and the Building Are on the Same Level, But the Track Is Depressed 25 Feet. The Angle Subtended by the Ends Of the Barrier and the NAL Is 120 Degrees.

    The Noise Attenuation Provided by This Barrier Is ____________________ Decibels.

    Is This Sufficient? ____

30. A Three Story Building Is Exposed to Noise Levels of 67 LDN from Automobiles and 71 LDN from Trucks. The Barrier Is 16 Feet High and Is Located 36 Feet from the Source and 56 Feet from the Building. The Source, the Barrier and the Building Are All At the Same Level. The Angle Subtended by the Barrier Ends and the NAL Is 130 Degrees.

    The Noise Attenuation Provided by This Barrier Is ____________________ Decibels.

    Is This Sufficient? ____

Noise Assessment Guidelines Workbook
Answers

Problem

1. 68 LDN (67–61 = 6, Add 1dB (From Table) to 67 = 68 LDN)
2. 66 LDN (63–63 = 0, Add 3dB (From Table) to 63 = 66 LDN)
3. 69 LDN (69–51 = 0, Add 0dB to 69 = 69 LDN)
4. 67 LDN (65–62 = 3, Add 1.8dB to 65, Round Off to Nearest Whole Number, 66.8 = 67 LDN)
5. 73 LDN (72–65 = 5, Add 1.2 = 73.2 = 73 LDN)
6. 72 LDN (63–59 = 4, Add 1.5 = 64.5, 71–64.5 = 6.5
Interpolate From Table: 6 = 1.0, 7 = .8
6.5 = .9) 71 + .9 = 71.9 = 72 LDN)

7. 76 LDN (67–61 = 6, Add 1.0 = 68, 72–68 = 4, Add 1.5 = 73.5, 73.5–73 = .5, Interpolate From Table, Add 2.75 = 76.25 = 76 LDN)

8. 49 Feet (76 + 22 = 98 – 2 = 49)
9. 72 Feet (84 + 60 = 144 – 2 = 72)

10. Adjustment Factors Needed: Speed and Night-Time Percentage

    Value of Factors: Speed = Autos .30
    Trucks .81
    Nighttime
    Percentage .81

    Note—You Must Have Different Speed Adjustments for Autos and Trucks.

11. Adjustment Factors Needed: Speed and Stop and Go Traffic
    Value of Factors: Speed .67
    Stop and Go .70

12. Adjustment Factors Needed: Gradient, Speed and Nighttime Percentage

    Value of Factors: Gradient 1.4
    Speed = Autos .30
    Trucks .81
    Nighttime
    Percentage .81

13. Adjustment Factors Needed: Nighttime Percentage, Speed, Bolted Track

    Value of Factors: Nighttime
    Percentage 1.57
    Speed = Engines .75
    Cars 1.78
    Bolted Track 4

    Note—You Must Have Different Speed Adjustments for Engines and Cars.

14. Adjustment Factors Needed: Nighttime Percentage and Speed

    Value of Factors: Nighttime
    Percentage .62
    Speed = Engines 3.0
    Cars .11

15. Adjustment Factors Needed: Nighttime Percentage and Bolted Track

    Value of Factors: Nighttime
    Percentage 1.19
    Bolted Track 4

16. Combined Noise Level = 62 LDN (If Your Answer Is Plus or Minus 1dB Its OK - Between Rounding Off and the Large Scale on the Nomographs, That's Close Enough)

Worksheet C
Roadway Noise — Page 1 — Noise Assessment Guidelines

List all major roads within 1000 ft of the site:

1. ____
2. ____
3. ____
4. ____

Necessary Information	Road 1	Road 2	Road 3	Road 4
1. Distance in feet from the NAL to the edge of the road				
a. nearest lane	310			
b. farthest lane	358			
c. average (effective distance)	334			
2. Distance to stop sign	400			
3. Road gradient in percent	1%			
4. Average speed in mph				
a. Automobiles	40			
b. heavy trucks - uphill	40			
c. heavy trucks - downhill	40			
5. 24 hour average number of automobiles and medium trucks in both directions (ADT)				
a. automobiles	17000			
b. medium trucks	1500			
c. effective ADT (a + (10xb))	32000			
6. 24 hour average number of heavy trucks				
a. uphill	200			
b. downhill	200			
c. total	400			
7. Fraction of nighttime traffic (10:00 p.m. to 7 a.m.)	20%			
8. Traffic projected for what year?	—			

Worksheet C
Roadway Noise — Page 2 — Noise Assessment Guidelines

Adjustments for Automobile Traffic

	9 Stop and-go Table 3	10 Average Speed Table 4	11 Night-Time Table 5	12 Auto ADT (line 5c)	13 Adjusted Auto ADT	14 DNL (Workchart 1)	15 Barrier Attenuation	16 Partial DNL
Road No. 1	.70	x .53	x 1.19	x 32000	= 14128	67	- 0	= 67
Road No. 2		x	x	x	=		-	=
Road No. 3		x	x	x	=		-	=
Road No. 4		x	x	x	=		-	=

Adjustments for Heavy Truck Traffic

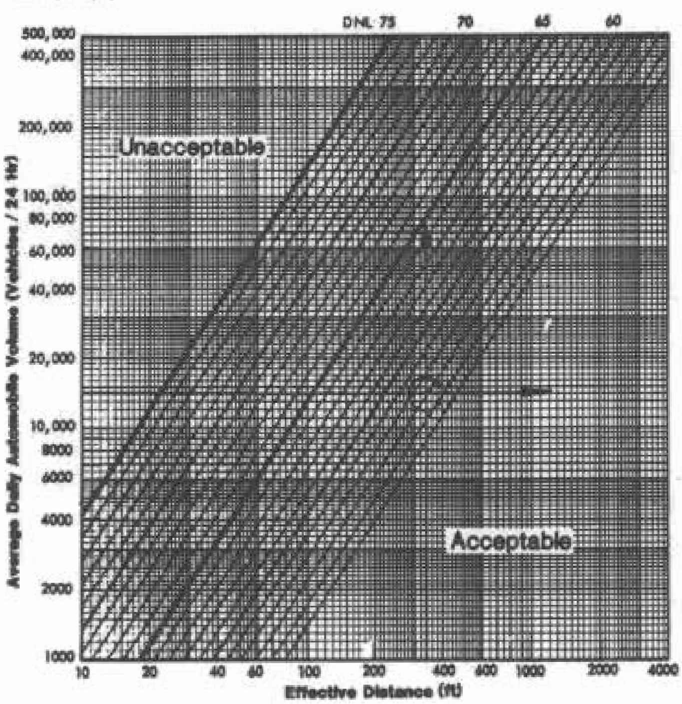
		17 Gradient Table 6	18 Average Speed Table 7	19 Truck ADT 6	20	21	22 Stop and-go Table 8	23 Night Time Table 5	24 Adjusted Truck ADT	25 DNL (Workchart 2)	26 Barrier Adj.	27 Partial DNL
Road No. 1	Uphill	—	x .81	x 200	= 162							
						Add 324	x 1.8	x 1.19	= 694	60	- 0	= 60
	Downhill		.81	x 200	= 162							
Road No. 2	Uphill		x	x	=							
						Add	x	x	=		-	=
	Downhill			x	=							
Road No. 3	Uphill		x	x	=							
						Add	x	x	=		-	=
	Downhill			x	=							
Road No. 4	Uphill		x	x	=							
						Add	x	x	=		-	=
	Downhill			x	=							

Combined Automobile & Heavy Truck DNL

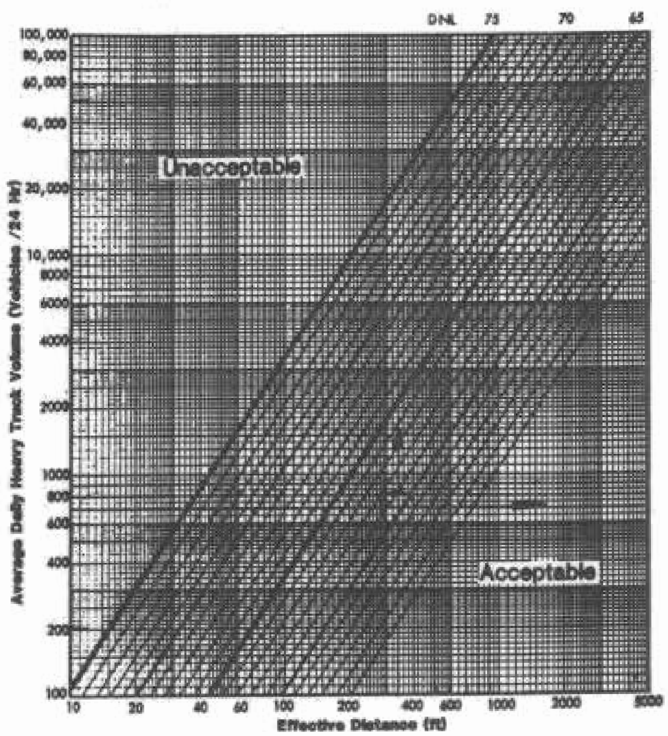
Road No. 1 62 Road No. 2 ____ Road No. 3 ____ Road No. 4 ____ Total DNL for All Roads 62

Signature ____________________ Date ________

Workchart 1
Autos (55 mph)



Workchart 2
Heavy Trucks (55 mph)



17. Combined Noise Level = 74 LDN (+ OR − 1 dB)

Worksheet C
Roadway Noise — Page 1 — Noise Assessment Guidelines

List all major roads within 1000 ft of the site:

1. ______
2. ______
3. ______
4. ______

Necessary Information	Road 1	Road 2	Road 3	Road 4
1. Distance in feet from the NAL to the edge of the road				
a. nearest lane	125	45		
b. farthest lane	233	93		
c. average (effective distance)	179	69		
2. Distance to stop sign	250	100		
3. Road gradient in percent	3%	1%		
4. Average speed in mph				
a. Automobiles	30	30		
b. Heavy trucks - uphill	30	30		
c. Heavy trucks - downhill	30	30		
5. 24 hour average number of automobiles and medium trucks in both directions (ADT)				
a. automobiles	22000	14000		
b. medium trucks	2000	700		
c. effective ADT (a + (10xb))	42000	21000		
6. 24 hour average number of heavy trucks				
a. uphill	475	300		
b. downhill	475	300		
c. total	950	600		
7. Fraction of nighttime traffic (10:00 p.m. to 7 a.m.)	10%	20%		
8. Traffic projected for what year?	–	–		

Worksheet C
Roadway Noise — Page 2 — Noise Assessment Guidelines

Adjustments for Automobile Traffic

	9 Stop and go Table 3	10 Average Speed Table 4	11 Night Time Table 5	12 Auto ADT (line 5c)	13 Adjusted Auto ADT	14 DNL (Workchart 1)	15 Barrier Attenuation	16 Partial DNL
Road No. 1	.48	.30	.81	42000	4899	57	0	57
Road No. 2	.25	.30	1.19	21000	1874	59	0	59
Road No. 3								
Road No. 4								

Adjustments for Heavy Truck Traffic

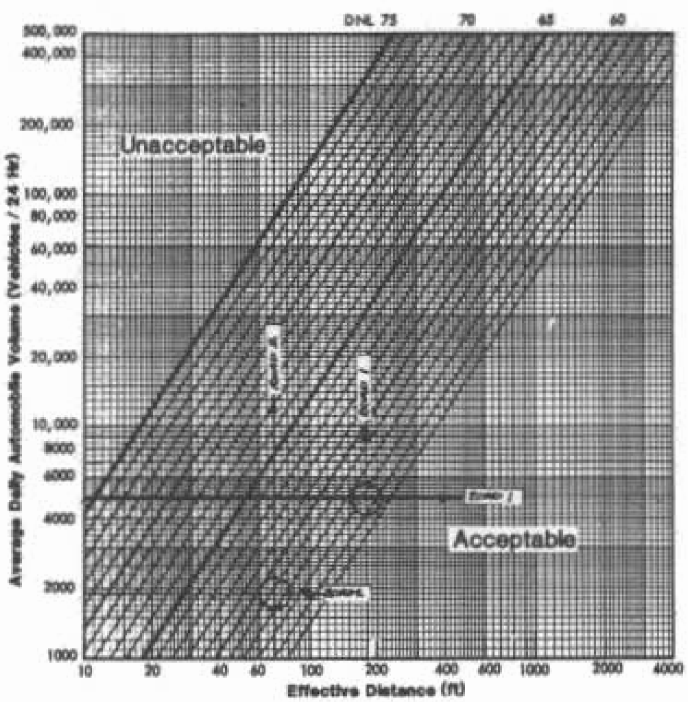
		17 Gradient Table 6	18 Average Speed Table 7	19 Truck ADT	20	21	22 Stop and go Table 8	23 Night Time Table 9	24 Adjusted Truck ADT	25 DNL (Work Chart 2)	26 Barrier Atn.	27 Partial DNL
Road No. 1	Uphill	1.7	.81	475	654							
					Add	1039	1.8	.81	1515	68	0	68
	Downhill		.81	475	385							
Road No. 2	Uphill	–	.81	300	243							
					Add	486	1.1	1.19	1041	72	0	72
	Downhill		.81	300	243							
Road No. 3	Uphill											
					Add							
	Downhill											
Road No. 4	Uphill											
					Add							
	Downhill											

Combined Automobile & Heavy Truck DNL

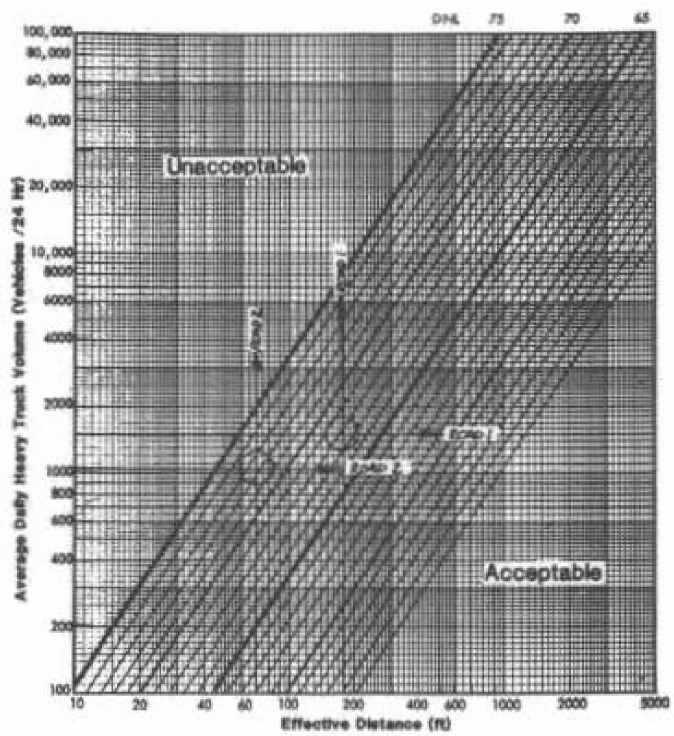
Road No. 1 68 Road No. 2 72 Road No. 3 ____ Road No. 4 ____ Total DNL for All Roads 74

Signature ______________________ Date __________

Workchart 1
Autos (55 mph)



Workchart 2
Heavy Trucks (55 mph)



18. Combined Noise Level = 71 LDN

Note—In Order to Complete Column 18 for Railway #2 You Must Find the Average Number of Cars Per Train. Multiply the Number of Diesel Trains Times the Number of Cars Per Train (20 × 45 = 900). Multiply the Number of Electrified Trains Times the Number of Cars Per Train (2 × 15 = 30). Add the Two Totals Together and Divide By the Total Number of Trains (900 + 30 = 930 − 22 = 42).

Worksheet D
Railway Noise

Page 2

Noise Assessment Guidelines

Adjustments for Diesel Locomotives

	9 No. of Locomotives	10 Average Speed Table 9	11 Horns (enter 10)	12 Night-time Table 8	13 No. of Trains (line 3a)	14 Adj. No. of Opns	15 DNL Workchart 3	16 Barrier Attn.	17 Partial DNL
Railway No. 1	1.6	1.0	–	1.38	35	72	70	0	72
Railway No. 2	1	.75	–	1.0	20	15	58	0	58
Railway No. 3									

Adjustments for Railway Cars or Rapid Transit Trains

	18 Number of cars /50	19 Average Speed Table 10	20 Bolted Rails (enter 4)	21 Night-time Table 8	22 No. of Trains Line 3a or 3b	23 Adj. No. of Opns	24 DNL Workchart 4	25 Barrier Attn.	26 Partial DNL
Railway No. 1	1.4	1.0	4	1.38	35	270	64	0	64
Railway No. 2	.84	1.78	4	1.38	22	182	57	0	67
Railway No. 3									

Combined Locomotive and Railway Car DNL

Railway No. 1 71 Railway No. 2 61 Railway No. 3 71 Total DNL for all Railways

Signature ______ Date ______

19. Combined Noise Level = 76 LDN

Worksheet D
Railway Noise

Page 2

Noise Assessment Guidelines

Adjustments for Diesel Locomotives

	9 No. of Locomotives	10 Average Speed Table 9	11 Horns (enter 10)	12 Night-time Table 8	13 No. of Trains (line 3a)	14 Adj. No. of Opns	15 DNL Workchart 3	16 Barrier Attn.	17 Partial DNL
Railway No. 1	2.5	.88	–	1.19	34	89	75	0	75
Railway No. 2	2	1.50	–	1.38	12	50	70	0	70
Railway No. 3									

Adjustments for Railway Cars or Rapid Transit Trains

	18 Number of cars /50	19 Average Speed Table 10	20 Bolted Rails (enter 4)	21 Night-time Table 8	22 No. of Trains Line 3a or 3b	23 Adj. No. of Opns	24 DNL Workchart 4	25 Barrier Attn.	26 Partial DNL
Railway No. 1	1.5	1.39	–	1.19	34	84	63	0	63
Railway No. 2	.80	.44	4	1.38	12	23	55	0	55
Railway No. 3									

Combined Locomotive and Railway Car DNL

Railway No. 1 75 Railway No. 2 70 Railway No. 3 ______ Total DNL for all Railways 76

Signature ______ Date ______

20. Combined Noise Level = 75 LDN

Worksheet C
Roadway Noise

Page 1

Noise Assessment Guidelines

List all major roads within 1000 ft of the site:

1. ______
2. ______
3. ______
4. ______

Necessary Information	Road 1	Road 2	Road 3	Road 4
1. Distance in feet from the NAL to the edge of the road				
a. nearest lane	100	45	52	
b. farthest lane	208	75	92	
c. average (effective distance)	154	60	72	
2. Distance to stop sign	–	175	400	
3. Road gradient in percent	1%	4%	1%	
4. Average speed in mph				
a. Automobiles	65	40	25	
b. heavy trucks - uphill	55	40	25	
c. heavy trucks - downhill	55	40	25	
5. 24 hour average number of automobiles and medium trucks in both directions (ADT)				
a. automobiles	40000	15800	5000	
b. medium trucks	–	800	1050	
c. effective ADT (a + (10xb))	40000	24000	15500	
6. 24 hour average number of heavy trucks				
a. uphill	–	160	87	
b. downhill	–	160	88	
c. total	–	320	175	
7. Fraction of nighttime traffic (10:00 p.m. to 7 a.m.)	15%	20%	20%	
8. Traffic projected for what year?	–	–	–	

Worksheet C
Roadway Noise

Page 2

Noise Assessment Guidelines

Adjustments for Automobile Traffic

	9 Stop and go Table 3		10 Average Speed Table 4		11 Night Time Table 5		12 Auto ADT (line 5c)		13 Adjusted Auto ADT	14 DNL (Worksheet 1)		15 Barrier Attenuation		16 Partial DNL
Road No. 1	~~0~~	x	1.0	x	1.0	x	40000	=	40000	67	–	0	=	67
Road No. 2	.36	x	.58	x	1.19	x	24000	=	5450	65	–	0	=	65
Road No. 3	.70	x	.21	x	1.19	x	15500	=	2711	60	–	0	=	60
Road No. 4		x		x		x		=			–		=	

Adjustments for Heavy Truck Traffic

		17 Gradient Table 6		18 Average Speed Table 7		19 Truck ADT		20	21		22 Stop and-go Table 8		23 Night Time Table 5		24 Adjusted Truck ADT	25 DNL (Work chart 2)		26 Barrier Att.		27 Partial DNL
Road No. 1	Uphill	–	x	–	x	–	=	–												
									Add	–	x	–	x	–	=	–	–	–	=	–
	Downhill			–	x	–	=	–												
Road No. 2	Uphill	2.0	x	.81	x	160	=	259												
									Add	389	x	1.8	x	1.19	=	833	72	– 0	=	72
	Downhill			.81	x	160	=	130												
Road No. 3	Uphill	1.0	x	.81	x	87	=	70												
									Add	141	x	1.8	x	1.19	=	303	67	– 0	=	67
	Downhill			.81	x	88	=	71												
Road No. 4	Uphill		x		x		=													
									Add		x		x		=			–	=	
	Downhill				x		=													

Combined Automobile & Heavy Truck DNL

Road No. 1 67 Road No. 2 73 Road No. 3 68 Road No. 4 ______ Total DNL for All Roads 75

Signature ______ Date ______

21. Combined Noise Level = 81 LDN

To Solve This Problem You Must Add Some More Lines to the Workchart for Engines Because the Workchart as Set up Does Not Go High Enough. There Are A Variety of Ways to Do This But One of the Easiest Is to Take A Piece of Blank Paper (A 3 × 5 Card Does Very Well) Place the Edge of the Paper Along Either the Top Or Bottom Edge of the Workchart and Mark Where the LDN Lines Fall Along the Edge of the Blank Paper. Then Once You Have Drawn Your Distance and Operations Lines on the Work Chart, You Take Your Paper with the Line Markings and Lay It along the Line for Adjusted Operations with the Mark Farthest to the Right Lined up with the 75 LDN Line. Now Just Count over until You Reach the Intersection of the Operations and Distance Lines.

Worksheet D
Railway Noise

Page 2

Noise Assessment Guidelines

Adjustments for Diesel Locomotives

	9 No. of Locomotives / 2		10 Average Speed Table 9		11 Horns (enter 10)		12 Night-time Table 8		13 No. of Trains (line 3a)		14 Adj. No. of Opns.	15 DNL Workchart 3		16 Barrier Atn.		17 Partial DNL
Railway No. 1	1.5	x	1.0	x	10	x	1.19	x	30	=	535	81	-	0	=	81
Railway No. 2		x		x		x		x		=			-		=	
Railway No. 3		x		x		x		x		=			-		=	

Adjustments for Railway Cars or Rapid Transit Trains

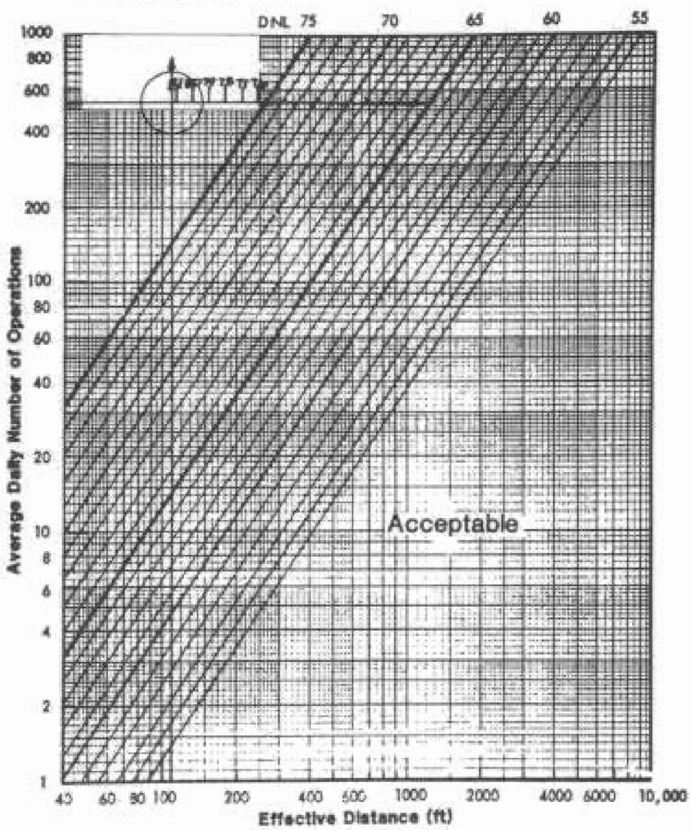
	18 Number of cars / 50		19 Average Speed Table 10		20 Bolted Rails (enter 4)		21 Night-time Table 8		22 No. of Trains (Line 2a or 2b)		23 Adj. No. of Opns.	24 DNL Work-chart 4		25 Barrier Atn.		26 Partial DNL
Railway No. 1	1.0	x	1.0	x	4	x	1.19	x	30	x	143	63	-	0	=	63
Railway No. 2		x		x		x		x		x			-		=	
Railway No. 3		x		x		x		x		x			-		=	

Combined Locomotive and Railway Car DNL

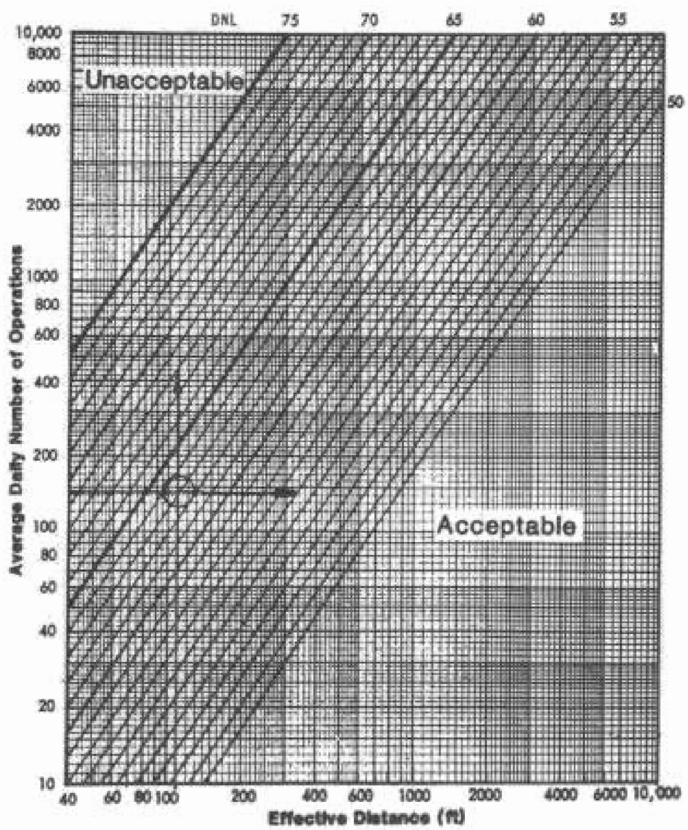
Railway No. 1 81 Railway No. 2 ______ Railway No. 3 ______ Total DNL for all Railways 81

Signature ______________________ Date ______________

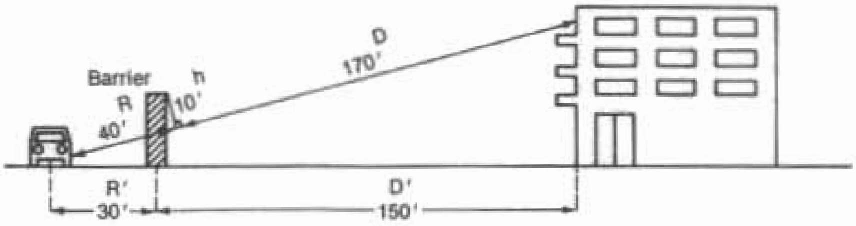
Workchart 3
Railroads - Diesel Locomotives



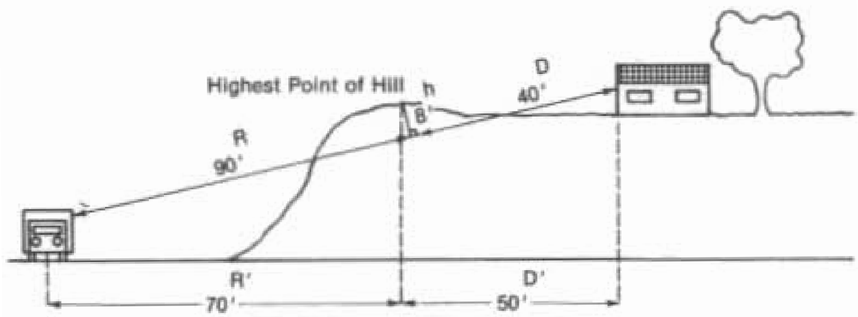
Workchart 4
Railroads - Cars and Rapid Transit



22. H = 10 Feet, R = 40 Feet, R' = 30 Feet, D = 170 Feet, D' = 150 Feet

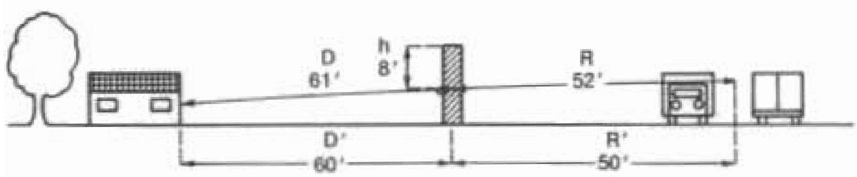


23. H = 8 Feet, R = 90 Feet, R' = 70 Feet, D = 40 Feet, D' = 50 Feet



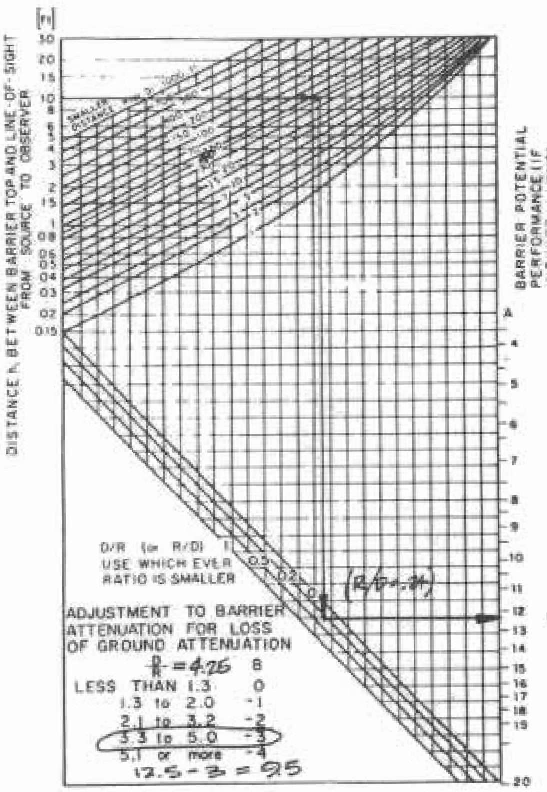
Note—The Line of Sight Line Starts Above the Road Level Because of the Trucks.

24. H = 8 Feet, R = 52 Feet, R' = 50 Feet, D = 61 Feet, D' = 60 Feet

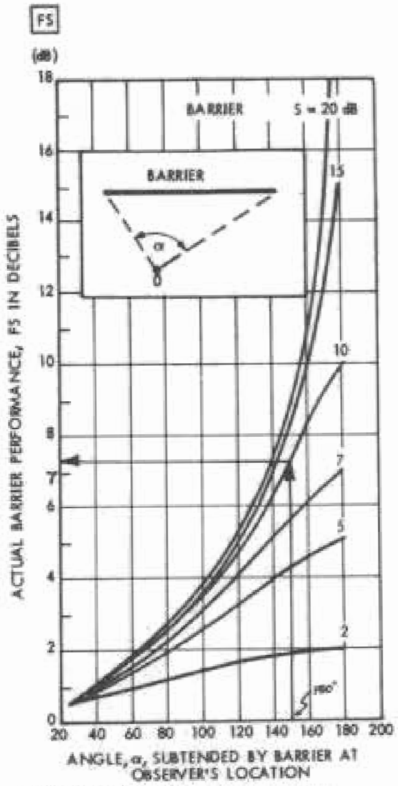


25. The Noise Attenuation Provided Is 7 Decibels

Workchart 6
Noise Barrier



Workchart 7

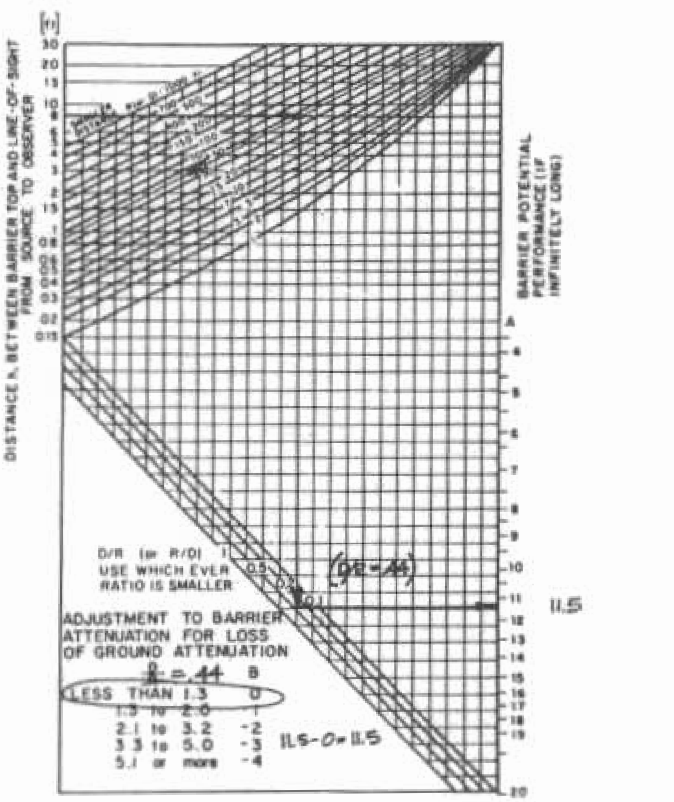


Correction to be applied to barrier potential in order to find the actual performance of the barrier of the same construction but of finite length.

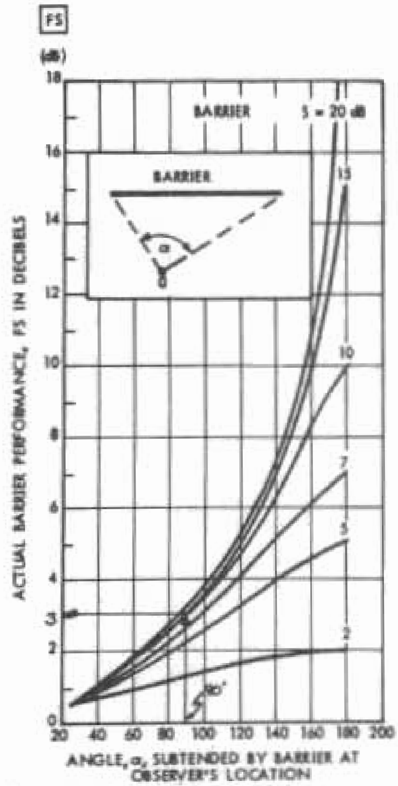
26. The Noise Attenuation Provided Is 3 Decibels

Note—When the Curves ARe So Close Together Don't Worry About Extrapolating. In This Case You Couldn't Anyway, the 15 dB and 10 dB Curves Have Merged.

Workchart 8
Noise Barrier



Workchart 7

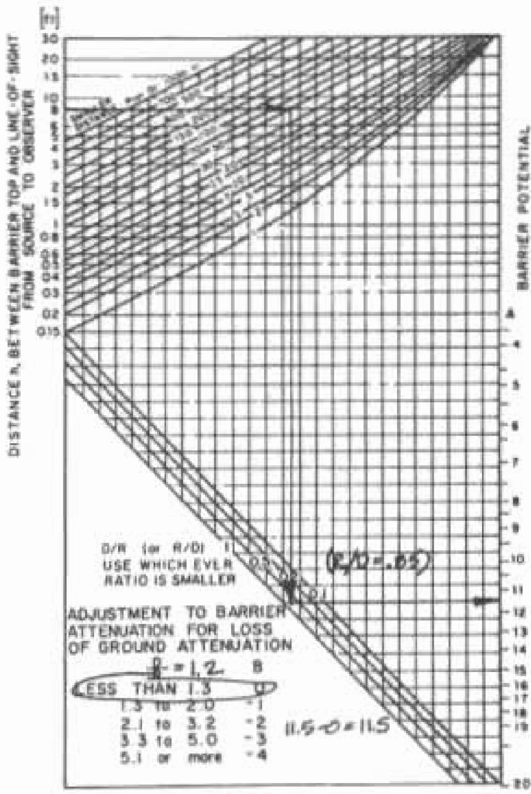


Correction to be applied to barrier potential in order to find the actual performance of the barrier of the same construction but of finite length.

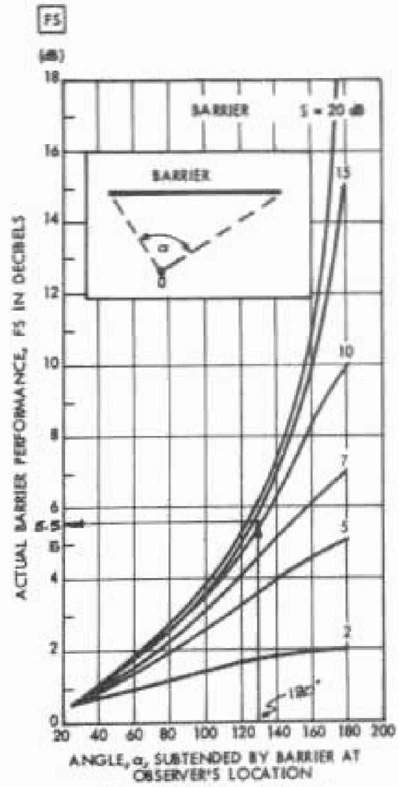
27. The Noise Attenuation Provided Is 6 Decibels (5.5 Rounded Up)

Note—Again You Have Problems With Extrapolating—Don't Worry About Being Too Precise.

Workchart 6
Noise Barrier



Workchart 7



Correction to be applied to barrier potential in order to find the actual performance of the barrier of the same construction but of finite length.

28. The Noise Attenuation Provided by This Barrier Is 4 dB. This Is Sufficient

Note—Don't Forget That the Height of the observor Is 5' Less Than the Total Height of the Building and the Height of the Building Is 10 Feet Times the Number of Stories. And Did You Remember to Make the Adjustment for Ground Attenuation Loss.

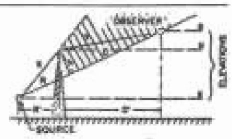
Workchart 5
Noise Barrier

To find R, D and h from Site Elevations and Distances

Fill out the following worksheet (all quantities are in feet):

Enter the values for:

H = 15 R' = 40
S = 0 D' = 20
O = 15

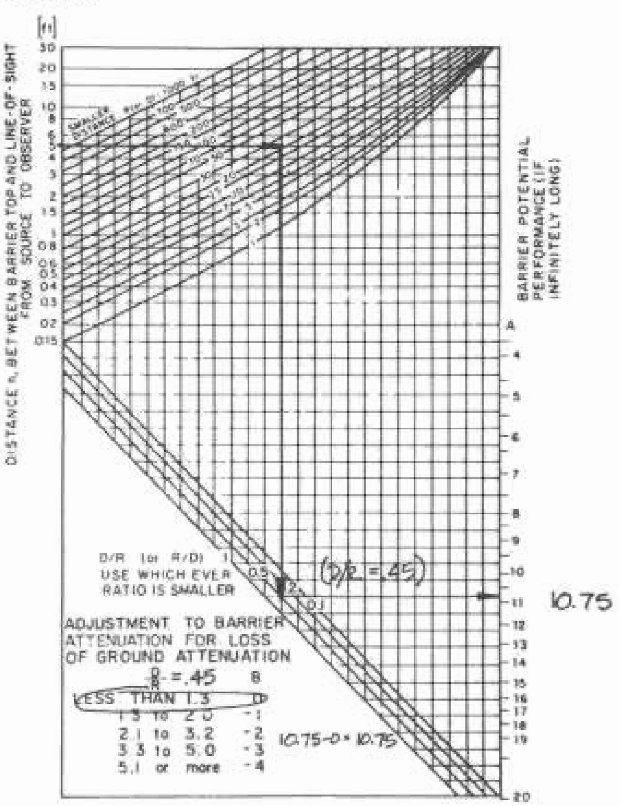


1. Elevation of barrier top minus elevation of source	[H 15]	−	[S 0]	=	[1 15]
2. Elevation of observer minus elevation of source	[O 15]	−	[S 0]	=	[2 15]
3. Map distance between source and observer (R' + D')					[3 60]
4. Map distance between barrier and source (R')					[4 40]
5. Line 2 divided by line 3	[2 15]	÷	[3 60]	=	[5 .25]
6. Square the quantity on line 5 (i.e., multiply it by itself); always positive	[5 .25]	×	[5 .25]	=	[6 .0625]
7. 40% of line 6	[0.4]	×	[6 .0625]	=	[7 .025]
8. One minus line 7	[1.0]	−	[7 .025]	=	[8 .975]
9. Line 5 times line 4 (will be negative if line 2 is negative)	[5 .25]	×	[4 40]	=	[9 10]
10. Line 1 minus line 9	[1 15]	−	[9 10]	=	[10 5]
11. Line 10 times line 8	[10 5]	×	[8 .975]	=	[11 4.9] = h
12. Line 5 times line 10	[5 .25]	×	[10 5]	=	[12 1.25]
13. Line 4 divided by line 8	[4 40]	÷	[8 .975]	=	[13 41]
14. Line 13 plus line 12	[13 41]	+	[12 1.25]	=	[14 42] = R
15. Line 3 minus line 4	[3 60]	−	[4 40]	=	[15 20]
16. Line 15 divided by line 8	[15 20]	÷	[8 .975]	=	[16 20.5]
17. Line 16 minus line 12	[16 20.5]	−	[12 1.25]	=	[17 19] = D

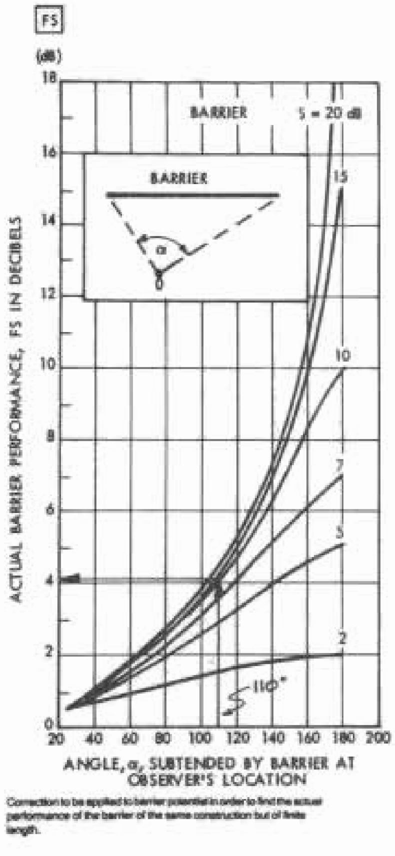
[Note: the values on line 2 may be negative, in which case so will the values on lines 5, 9, and 12; line 1 may also be negative. Remember, then, in lines 10, 14, and 17, that adding a negative number is the same as subtracting: x + (−y) = x − y. And subtracting a negative number is like adding: X − (−y) = x + y.]

Round off R and D to nearest integer, h to one decimal place.

Workchart 6
Noise Barrier



Workchart 7



Correction to be applied to barrier potential in order to find the actual performance of the barrier of the same construction but of finite length.

29. The Noise Attenuation Provided by This Barrier Is Approximately 5 dB for Both the Engines and the Railroad Cars.

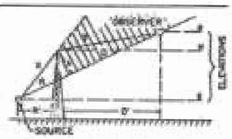
This Is Not Sufficient.

Note—You Were Supposed to Calculate Attenuation for Diesel Engines and Cars Separately Because the Source Heights Are Different. The Value of S for the Engines Should Have Been −10 and the Value of S for the Railroad Cars Should Have Been −25.

Workchart 5
Noise Barrier
To find R, D and h from Site Elevations and Distances

Enter the values for:

H= 12 R'= 40
S= −10 D'= 85
O= 25



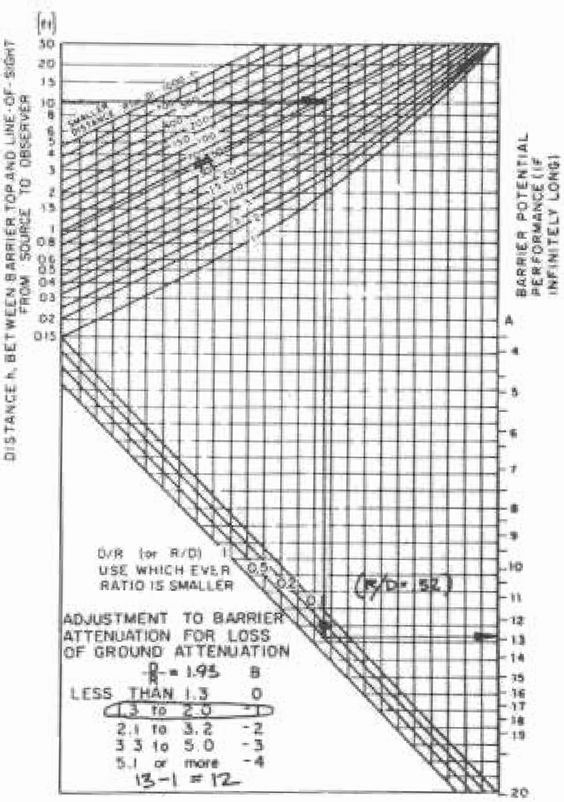
Fill out the following worksheet (all quantities are in feet):

1. Elevation of barrier top minus elevation of source	[H 12]	−	[S −10]	=	[1 22]		
2. Elevation of observer minus elevation of source	[O 25]	−	[S −10]	=	[2 35]		
3. Map distance between source and observer (R' + D')					[3 125]		
4. Map distance between barrier and source (R')					[4 40]		
5. Line 2 divided by line 3	[2 35]	÷	[3 125]	=	[5 .28]		
6. Square the quantity on line 5 (i.e., multiply it by itself); always positive	[5 .28]	×	[5 .28]	=	[6 .08]		
7. 40% of line 6	[.4]	×	[6 .08]	=	[7 .03]		
8. One minus line 7	[1.0]	−	[7 .03]	=	[8 .97]		
9. Line 5 times line 4 (will be negative if line 2 is negative)	[5 .28]	×	[4 40]	=	[9 11.2]		
10. Line 1 minus line 9	[1 22]	−	[9 11.2]	=	[10 10.8]		
11. Line 10 times line 8	[10 10.8]	×	[8 .97]	=	[11 10.5]	=	h
12. Line 5 times line 10	[5 .28]	×	[10 10.8]	=	[12 3]		
13. Line 4 divided by line 8	[4 40]	÷	[8 .97]	=	[13 41]		
14. Line 13 plus line 12	[13 41]	+	[12 3]	=	[14 44]	=	R
15. Line 3 minus line 4	[3 125]	−	[4 40]	=	[15 85]		
16. Line 15 divided by line 8	[15 85]	÷	[8 .97]	=	[16 88]		
17. Line 16 minus line 12	[16 88]	−	[12 3]	=	[17 85]	=	D

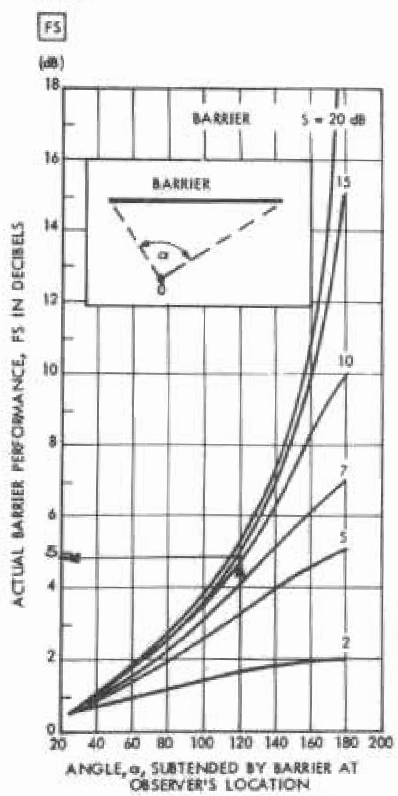
[Note: the value on line 2 may be negative, in which case so will the values on lines 5, 9, and 12; line 1 may also be negative. Remember, then, in lines 10, 14, and 17, that adding a negative number is the same as subtracting: $x+(-y)=x-y$. And subtracting a negative number is like adding: $x-(-y)=x+y$.]

Round off R and D to nearest integer, h to one decimal place.

Workchart 6
Noise Barrier



Workchart 7



Correction to be applied to barrier potential in order to find the actual performance of the barrier of the same construction but of finite length.

Workchart 5
Noise Barrier

To find R, D and h from Site Elevations and Distances

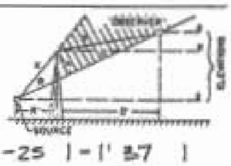
Fill out the following worksheet (all quantities are in feet):

Enter the values for:

H= 12 R'= 40

S= -25 D'= 85

O= 25

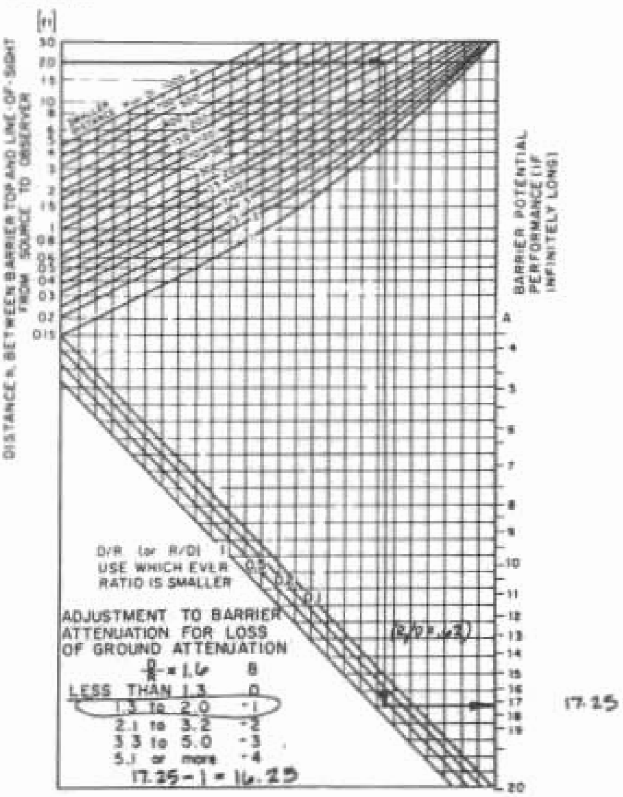


1. Elevation of barrier top minus elevation of source	[H 12] − [S −25]	= [1 37]	
2. Elevation of observer minus elevation of source	[O 25] − [S −25]	= [2 50]	
3. Map distance between source and observer (R' + D')		[3 125]	
4. Map distance between barrier and source (R')		[4 40]	
5. Line 2 divided by line 3	[2 50] ÷ [3 125]	= [5 .4]	
6. Square the quantity on line 5 (i.e., multiply it by itself), always positive	[5 .4] × [5 .4]	= [6 .16]	
7. 40% of line 6	[0.4] × [6 .16]	= [7 .06]	
8. One minus line 7	[1.0] − [7 .06]	= [8 .94]	
9. Line 5 times line 4 (will be negative if line 2 is negative)	[5 .4] × [4 40]	= [9 16]	
10. Line 1 minus line 9	[1 37] − [9 16]	= [10 21]	
11. Line 10 times line 8	[10 21] × [8 .94]	= [11 19.7]	= h
12. Line 5 times line 10	[5 .4] × [10 21]	= [12 8.4]	
13. Line 4 divided by line 8	[4 40] ÷ [8 .94]	= [13 42.6]	
14. Line 13 plus line 12	[13 42.6] + [12 8.4]	= [14 51]	= R
15. Line 3 minus line 4	[3 125] − [4 40]	= [15 85]	
16. Line 15 divided by line 8	[15 85] ÷ [8 .94]	= [16 90.4]	
17. Line 16 minus line 12	[16 90.4] − [12 8.4]	= [17 82]	= D

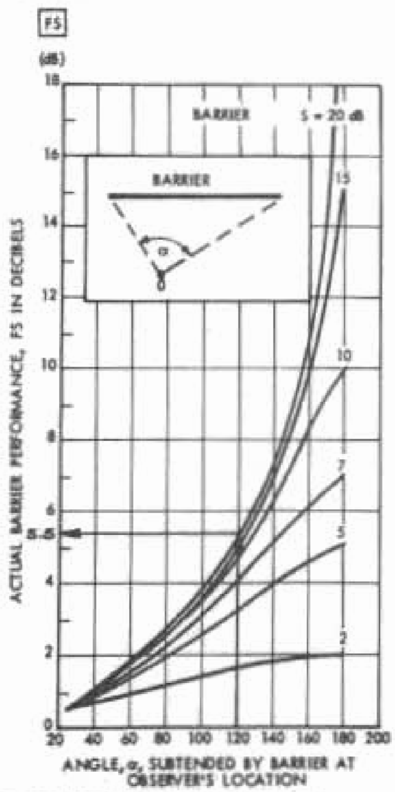
Note: the value on line 2 may be negative, in which case so will the values on lines 5, 9, and 12. line 1 may also be negative. Remember, then, in lines 10, 14, and 17, that adding a negative number is the same as subtracting: x + (−y) = x − y. And subtracting a negative number is like adding: x − (−y) = x + y.

Round off R and D to nearest integer, h to one decimal place.

Workchart 6
Noise Barrier



Workchart 7



Correction to be applied to barrier potential in order to find the actual performance of the barrier of the same construction but of finite length.

30. The Noise Attenuation Provided by This Barrier Is 3 dB for Trucks and 5 dB for Autos. The Combined Level Resulting Is 69 LDN.

This Is Not Sufficient

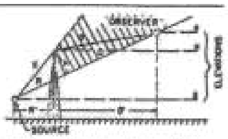
Note—You Must Calculate the Barrier Effect Separately for Autos and Trucks Because the Source Height is Different. Then Recombine levels.

Workchart 5
Noise Barrier
To find R, D and h from Site Elevations and Distances

Fill out the following worksheet (all quantities are in feet):

Enter the values for:

H= 16 R'= 36
S= 0 D'= 56
O= 25

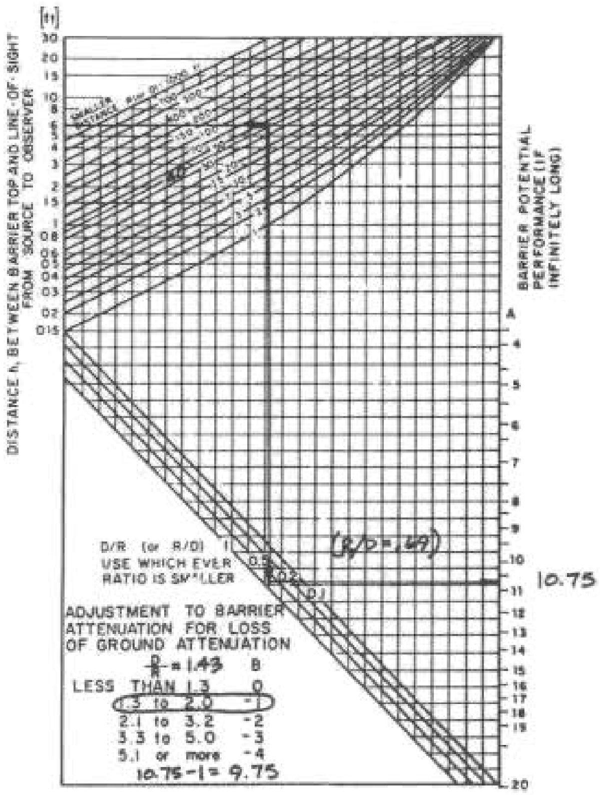


1. Elevation of barrier top minus elevation of source	[H 16]	−	[S 0]	=	[1 16]		
2. Elevation of observer minus elevation of source	[O 25]	−	[S 0]	=	[2 25]		
3. Map distance between source and observer (R' + D')					[3 92]		
4. Map distance between barrier and source (R')					[4 36]		
5. Line 2 divided by line 3	[2 25]	÷	[3 92]	=	[5 .27]		
6. Square the quantity on line 5 (i.e., multiply it by itself); always positive	[5 .27]	×	[5 .27]	=	[6 .07]		
7. 40% of line 6	[0.4]	×	[6 .07]	=	[7 .03]		
8. One minus line 7	[1.0]	−	[7 .03]	=	[8 .97]		
9. Line 5 times line 4 (will be negative if line 2 is negative)	[5 .27]	×	[4 36]	=	[9 9.7]		
10. Line 1 minus line 9	[1 16]	−	[9 9.7]	=	[10 6.3]		
11. Line 10 times line 8	[10 6.3]	×	[8 .97]	=	[11 6.1]	=	h
12. Line 5 times line 10	[5 .27]	×	[10 6.1]	=	[12 1.7]		
13. Line 4 divided by line 8	[4 36]	÷	[8 .97]	=	[13 37]		
14. Line 13 plus line 12	[13 37]	+	[12 1.7]	=	[14 39]	=	R
15. Line 3 minus line 4	[3 92]	−	[4 36]	=	[15 56]		
16. Line 15 divided by line 8	[15 56]	÷	[8 .97]	=	[16 58]		
17. Line 16 minus line 12	[16 58]	−	[12 1.7]	=	[17 56]	=	D

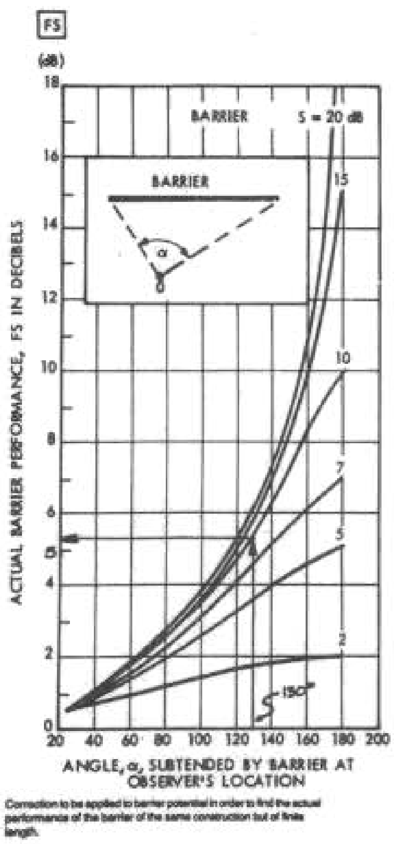
[Note: the value on line 2 may be negative, in which case so will the values on lines 5, 9, and 12; line 1 may also be negative. Remember, then, in lines 10, 14, and 17, that adding a negative number is the same as subtracting: x+(−y)=x−y. And subtracting a negative number is like adding: x−(−y)=x+y.]

Round off R and D to nearest integer, h to one decimal place.

Workchart 6
Noise Barrier



Workchart 7



Correction to be applied to barrier potential in order to find the actual performance of the barrier of the same construction but of finite length.

Workchart 5
Noise Barrier

To find R, D and h from Site Elevations and Distances

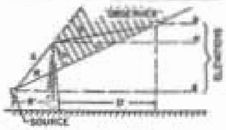
Fill out the following worksheet (all quantities are in feet)

Enter the values for:

H= 16   R'= 36

S= 8   D'= 56

O= 25

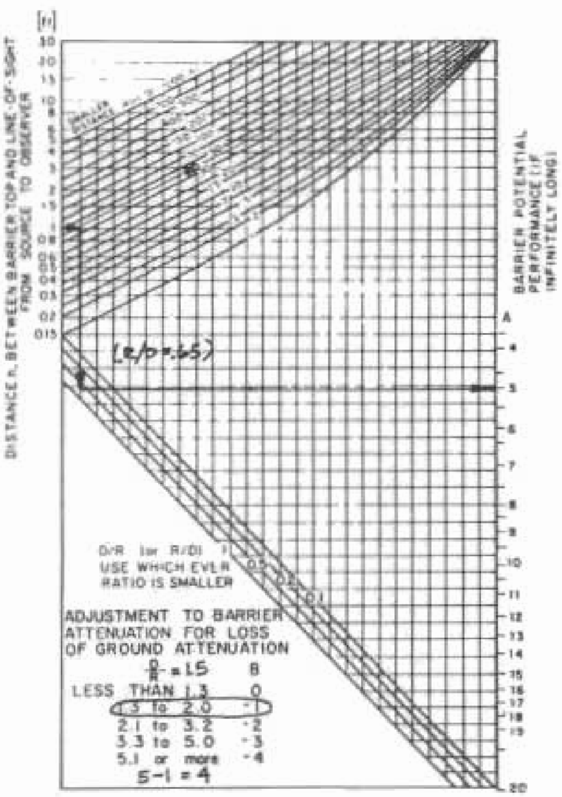


1. Elevation of barrier top minus elevation of source	[H 16]	−	[S 8]	=	[1 8]	
2. Elevation of observer minus elevation of source	[O 25]	−	[S 8]	=	[2 17]	
3. Map distance between source and observer (R' + D')					[3 92]	
4. Map distance between barrier and source (R')					[4 36]	
5. Line 2 divided by line 3	[2 17]	÷	[3 92]	=	[5 .2]	
6. Square the quantity on line 5 (i.e., multiply it by itself); always positive	[5 .2]	×	[5 .2]	=	[6 .04]	
7. 40% of line 6	[.4]	×	[6 .04]	=	[7 .02]	
8. One minus line 7	[1.0]	−	[7 .02]	=	[8 .98]	
9. Line 5 times line 4 (will be negative if line 2 is negative)	[5 .2]	×	[4 36]	=	[9 7]	
10. Line 1 minus line 9	[1 8]	−	[9 7]	=	[10 1]	
11. Line 10 times line 8	[10 1]	×	[8 .98]	=	[11 .98]	= h
12. Line 5 times line 10	[5 .2]	×	[10 1]	=	[12 .2]	
13. Line 4 divided by line 8	[4 36]	÷	[8 .98]	=	[13 37]	
14. Line 13 plus line 12	[13 37]	+	[12 .2]	=	[14 37]	= R
15. Line 3 minus line 4	[3 92]	−	[4 36]	=	[15 56]	
16. Line 15 divided by line 8	[15 56]	÷	[8 .98]	=	[16 57]	
17. Line 16 minus line 12	[16 57]	−	[12 .2]	=	[17 57]	= D

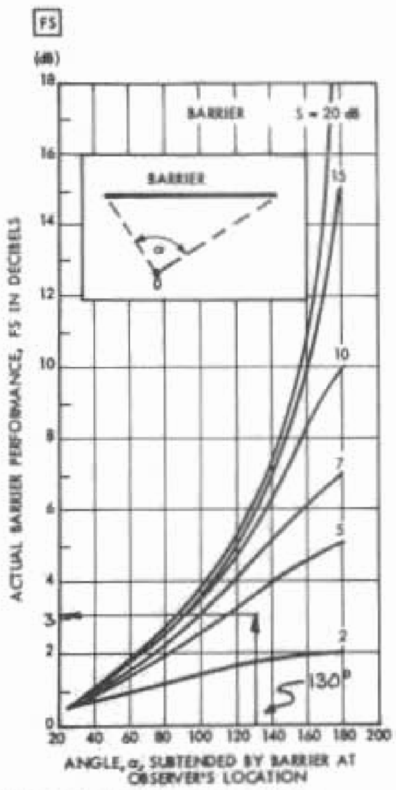
Note: the value on line 2 may be negative, in which case so will the values on lines 5, 9, and 12; line 1 may also be negative. Remember, then, in lines 10, 14, and 17, that adding a negative number is the same as subtracting: a + (−b) = a − b. And subtracting a negative number is like adding: a − (−b) = a + b.

Round off R and D to nearest integer, h to one decimal place.

Workchart 6
Noise Barrier



Workchart 7



Correction to be applied to barrier potential in order to find the actual performance of the barrier of the same construction but of finite length.

Chapter 7

The Use of Noise Measurements

Noise Calculations Are Best For HUD Use

There are two ways to determine noise levels for a site under review: the noise can be calculated or it can be measured. While one's first reaction might well be that it would obviously be better to go out and actually measure the noise levels at the site, calculated noise levels are really much better for implementing HUD's noise policy.

Calculated noise levels are developed using mathematical models that contain a variety of assumptions about the process of noise propagation as well as data on sound levels generated by typical sources (i.e. aircraft engines, automobile tires etc.). The model can be a complex computer model or it can be a simple desktop model such as the procedures in the *Noise Assessment Guidelines*. The models can also employ a variety of noise descriptors. (See chapter 1 for a discussion of noise descriptors.) Most noise studies done for the Federal Highway Administration, for example, use either the L_{10} or the L_{eq} noise descriptor. Many aircraft noise studies use the NEF or CNEL descriptor. All of these descriptors are compatible with the L_{dn} noise descriptor system that is preferred by HUD and the HUD noise regulation contains instructions for converting all of them into L_{dn}. (sections 51.106(a)(1) and (2))

Whether produced by a sophisticated computer model or by the desktop *Noise Assessment Guidelines*, calculated noise levels are more useful for HUD needs than measured levels for two significant reasons: The first is that with noise measurements you have no good way to take into account future changes in the future noise environment. The houses we help build today are going to be around for a long time and it is very important that we determine, to the extent we can, the noise environment that will exist throughout the life of the buildings. While there are clearly limitations on how far into the future we can reasonably project traffic levels for roads, railroads and airports, we can at least look 5 to 10 years ahead. The HUD noise regulation (24 CFR 51B) requires that "to the extent possible, noise exposure shall be projected to be representative of conditions that are expected to exist at a time at least 10 years beyond the date of the project or action under review." It is very easy to make these projections if you use the *Noise Assessment Guidelines* or a computer model to determine noise levels.

The second reason why we prefer that you calculate noise levels is that through the calculation process you can use monthly or yearly data to determine traffic levels. Thus you come up with a more typical picture of conditions. With noise measurements there is always the possibility that the day or even days chosen for measurements will not be typical and that the measurements may over or understate the problem. While the conscientious measurer will try to account for any unusual conditions, it isn't always possible. So long as cost considerations limit the number of days that measurements can be taken there will always be the problem of unrepresentative data. With calculations this isn't a problem. The computer model that generates contours for airports, for example, uses an entire years data to develop the average day. Certainly the results are more likely to be representative than the results that would be derived from just a few days measurements.

When Noise Measurements Are Useful

While it is the preferred procedure to calculate noise levels, there are a few situations where the noise models might not be accurate and it might be better to rely on measurements. One instance would be when there is insufficient or inadequate traffic data. Another case might be where you have a unique physical situation that is not accounted for in whatever mathematical model is available.

Obtaining good traffic data can be difficult. You may only be able to get gross data that simply lists total vehicles without making any distinctions between trucks and automobiles. Or you may not be able to get any reliable data on the percentage of traffic between 10 pm and 7 am. While the *Noise Assessment Guidelines* do contain some assumptions that you can use when you don't have all the data you need, there may be instances when you just don't think those assumptions would accurately portray the problem.

By the same token, there are certain physical situations that mathematical models such as the *Noise Assessment Guidelines* couldn't anticipate and therefore do not reflect in their formulas. For example, the *Guidelines* say that you don't have to calculate the noise levels for underground transit lines. Well what if the line is underground but there are large air vents that reach from the belowground tunnels to the surface? A great deal of noise can reach the surface through these vents but the *Noise Assessment Guidelines* don't have any way to take it into account. You couldn't treat it as if the subway line were aboveground because it isn't really and at least some of the noise is blocked. This would be a case where a noise measurement would probably be the best way to determine the noise levels. By the same token, the guidelines do not really take into account the sometimes significant amounts of reflected noise that can occur at urban sites surrounded by tall buildings, i.e. the canyon effect.

When Not to Use Measurements

One thing noise measurements should not be used for is to confirm or refute calculated noise levels, especially computer generated aircraft contours. Our experience with both the *Noise Assessment Guidelines* and with computer noise models is that both are quite accurate if done properly. If you are convinced that the calculations were done correctly, and if you believe that the data used were good, you should strongly discourage anyone who wants to take measurements because they think that measurements are inherently more accurate than calculations. Comparing measured noise levels to calculated levels is like comparing apples and oranges. The calculated noise levels should include projected traffic levels, the measured ones will not. The calculated levels will be based on daily traffic counts derived by averaging months of data, the measured levels will, at best, reflect just a few days. (This is particularly true for aircraft noise contours. The day-to-day operations of an airport can vary significantly depending upon weather conditions and any one or two days worth of measurements are very likely to show different levels from those generated by a computer model employing a year of data to derive an average day.)

If you have determined that noise measurements are appropriate, you must make sure that they are done properly, otherwise the data will be useless. There are four elements to proper measurements: 1) where the measurements are taken; 2) when they are taken; 3) the type of equipment used; and 4) the actual measurement procedure.

Where measurements should be taken: The locations for noise measurements should be selected using the same criteria you would use to select a Noise Assessment Location for a *Noise Assessment Guidelines* calculation. The *Noise Assessment Guidelines* recommend that "assessments of the noise exposure should be made at representative locations around the site where significant noise is expected." Further, the *Guidelines* state that when selecting these locations you should consider those buildings containing noise sensitive uses which are closest to the predominant noise sources. Where quiet outdoor space is desired at a site, you should also select points in the outdoor area in question. Specifically, the "relevant measurement location for buildings is a point 2 meters (6.5 feet) from the facade." If there are no buildings yet the measurement point should be 2 meters from the closest point setback requirements would allow a building facade.

When measurements should be taken: Because measurements are only going to be taken for a few days at best, special care should be taken to make sure that the days selected are representative of average traffic levels. For highways, avoid both Monday and Friday, particularly before or after a holiday. In fact holiday periods, such as the Christmas/New Years season, should be avoided entirely. Highway traffic, or rather more importantly, truck traffic is likely to be down during these periods and noise levels may be significantly lower than normal. On the other hand, holiday periods are often peak travel periods for airlines and measurements taken around airports then would show unusually high noise levels.

Whoever is taking the measurements should also check to make sure that there aren't any special circumstances that might affect traffic levels. For example road construction or repair work might divert additonal traffic onto the road being measured, or divert traffic away. In both cases the noise levels measured would not be representative.

And finally, noise measurements should not be taken during extreme weather conditions both because of the possible effects on traffic levels but also because the weather conditions can exaggerate the actual noise levels.

Ideally, noise measurements should be taken over several days spread over at least a few months. But given that time and money will normally preclude this, at least make sure the one or two days you can get are as close to typical as possible.

What equipment to use: There are many sound level meters on the market which are suitable for taking noise measurements for transportation sources. They need only to meet the requirements of American National Standard Specification for Type 1 Sound Level Meters: S1.4-1971. Type 1 sound level meters are "precision" meters and provide the most accurate measurements. They are also, of course, the most expensive. Fast time-averaging and A frequency weighting are to be used. The sound level meter with the A-weighting is progressively less sensitive to sound with frequencies below 1,000 hertz, somewhat as is the ear. With fast time averaging the sound level meter responds particularly to recent sounds almost as quickly as does the ear in judging the loudness of a sound. Fast time averaging has a time constant of about 1/8 second.

While a sound level measuring system that averages decibel readouts on a short term basis such as for every minute or every hour is acceptable, it would be far better if a system that actually provides a 24 hour integrated L_{dn} readout were used. Such a system eliminates the need for calculating the L_{dn} value, an area where many inexperienced consultants go astray. These systems are more expensive however, and the consultant who doesn't do much noise work is unlikely to have one.

Measurement procedures: Detailed procedures for making sound level measurements are spelled out in the American National Standards Institute's Standard Methods ANSI S1.2-1962(R1976) *American National Standard Method for the Physical Measurement of Sound* and ANSI S1.13-1971(R1976) *American National Standard Methods for the Measurement of Sound Pressure Levels.*

Some of the basic procedures that should be followed are:

1. Measurements should normally be made over a continuous 24 hour period. If this is not possible, measurements may be made over a period of days but still must cover the entire 24 hour period. The selection of the days becomes even more critical so that they are as similar as possible. Sampling is not acceptable.
2. The sound level meter must be calibrated before each use.
3. The sound level meter should be provided with a wind screen.
4. Care should be taken to insure that there are no temporary obstructions, such as parked trucks, between the meter and the source.

The Noise Study

The noise study prepared to describe the measurement results should contain at least the following:

1. A map showing where the measurements were taken
2. A vicinity map showing the site and the major noise sources
3. A chart indicating the date, the time, and weather conditions when measurements were taken at each measurement location
4. The type of microphone used
5. Any variations from ANSI procedures
6. The results of the measurements in L_{dn} for each measurement location
7. Any unusual conditions that existed during the measurement period—i.e. construction activity, major traffic tieup, etc.
8. If an integrating sound level meter was not used, the calculations used to derive the L_{dn} value.

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